ALLIED PAPER, INC./PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE

Spatial and Temporal PCB Trends in Carp and Smallmouth Bass Fillets

January 24, 2003

Prepared for:
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Fish Trend Analysis Executive Summary

1. Introduction

The Kalamazoo River drains an approximately 2000-square-mile watershed including nearly 400 miles of tributaries in Southwest Michigan. The lower approximately 80 miles of the river are part of the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. Portage Creek is a tributary joining the Kalamazoo River at Kalamazoo, Michigan, the lower three miles of which are also included in the Site. The presence of polychlorinated biphenyls (PCB) was first reported in the Kalamazoo River and biota of the river in 1971. This consequently resulted in consumption advisories for fish from the Kalamazoo River and Portage Creek. Several subsequent studies have documented the presence of PCB within the surface water, sediments, floodplain soil, and biota of both the Kalamazoo River and Portage Creek, as well as in landfills adjacent to both surface water bodies. In an effort to monitor human-health and ecological risk on the river system, samples of common carp (*Cyprinus carpio*), smallmouth bass (*Micropterus dolomieui*), and a variety of other species have been collected at 17 sites within the Kalamazoo River and Portage Creek.

Assessment of the effectiveness of remedial alternatives on the Kalamazoo River system requires evaluation of future risks to human and ecological health, and quantification of uncertainty in those predictions. Risks result from contact between ecological and human receptors that are of sufficiently long duration and of sufficient intensity to elicit adverse effects. In this region, human health risks from chlorinated organic compounds such as PCB are primarily associated with ingestion of contaminated fish tissue. At all superfund sites, a no-action alternative must be evaluated and is the basis to which the cost-effectiveness of other alternatives is compared; this requires an understanding of the likely effect of no action. Among other indices, the National Research Council research recommends PCB concentration in fish tissue as an indicator of remedial performance. Therefore, estimates of current and future fish-tissue concentrations are necessary to provide a baseline against which other alternatives can be compared. An estimate of uncertainty in these predictions is necessary in order to determine the adequacy of available data to compare competing alternatives.

2. Objectives

The primary objectives of the report are to: (1) quantify current PCB concentrations in carp and smallmouth bass fillets; (2) describe spatial and recent temporal trends in PCB concentration in carp and smallmouth bass fillets; (3) describe near future trends in PCB concentration through 2020; and (4) compare PCB concentrations in fish at the site to those at inland rivers and great lakes in Michigan.

3. Rationale

The Kalamazoo River Study Group (KRSG) has used temporal trends in PCB concentration in fish tissue samples from Lake Allegan and Plainwell impoundment to support their hypothesis that natural recovery may be a viable remedial alternative for the Kalamazoo River. KRSG has expressed these temporal trends in terms of half-times which are based on the assumption of a first order decay model. These first-order concentration forecasts require that future PCB concentrations continue to decay at the same average rate that has been observed since the early 1980s. While recent fillet-PCB concentrations are lower than those in the early to mid 1980s, these declines may be due to a combination of factors including: (1) restrictions on manufacture and discharge of PCBs into the environment; (2) active control of PCB sources to the river, (3) temporal covariation with fish length and lipid content and; (3) natural recovery. Similar temporal trends have been observed at the Hudson, Fox and Saginaw rivers (NRC, 2001; pp. 201-205) Data collected more recently at some sites suggests that current PCB concentrations at the site may be higher than exponential decay rates would have predicted. It has been noted that decay rates in PCB concentration in salmonids in Lake Michigan were slower in the 1990s than would have been expected under the first order decay assumption. We adjusted wet-weight PCB concentrations for covariation with length and lipid and then modeled these adjusted concentrations using the mixed order model. In this way, the resulting estimates of current and future PCB concentrations are adjusted for covariation with length and lipid-content, and take into account that temporal trends may not follow exponential decay assumptions.

4. Findings and Conclusions

4.1 General Findings

- PCB concentration in fillet and whole-body samples varied with fish-length and lipid content. Temporal forecasts and spatial comparisons that ignore these factors will lead to erroneous conclusions.

- Under a no-action alternative, MDCH fish consumption advisories are likely to be in place throughout the site for carp and at some ABSAs for smallmouth bass through 2020.

- Assuming that PCB concentration will decay exponentially in the future may result in overly optimistic projections of the performance of natural attenuation as a remedial alternative.

- Forecasted PCB concentrations in 2020 are reliable to approximately one order of magnitude. The existing temporal record is not adequate to make definitive statements regarding the effectiveness of natural recovery.

- Removal of contaminated sediments from the former Bryant Mill Pond appears to have resulted in at a 20-year acceleration in the rate of PCB reduction in carp fillets.

- The performance of the former Bryant Mill Pond removal action suggests that environmental dredging can be successful when contaminant deposits are properly delineated and a conservative approach is used, targeting all potentially contaminated sediments for removal.

- With the exception of Lake Erie, PCB concentrations in whole-body carp at Lake Allegan are the highest of all inland-river and great lakes sites regularly monitored by MDEQ.

4.2 Fillet PCB as an Indicator of Site Conditions

In general, after controlling for variations in lipid and length distributions, fish within the superfund site are exposed to and have accumulated higher PCB concentrations than those upstream of the site (Battle Creek, Morrow Pond; Figure 1). For carp, exposure to PCB increases with distance downstream from Morrow Pond with a maximum at Trowbridge Impoundment. Carp exposures to PCB at Lake Allegan, New Richmond and Saugatuck are lower than at Trowbridge, but similar to Plainwell and Otsego City Impoundments. It is interesting to note that although wet-weight concentrations at Plainwell are much higher than those at Lake Allegan, after controlling for length and lipid variation, fillet concentrations are similar. This indicates that environmental conditions at each of these sites are similar.

Adjusted PCB concentration based on site-wide adjustments is a general indicator of fish bioaccumulation of PCB. Since the early to mid 1980s, fish bioaccumulation of PCB contamination at most ABSA has declined. The rate of these declines varies with species, location and time. For example at Mosel Avenue from 1990 through 2001, adjusted PCB concentration in carp fillets dropped at an annualized rate of 4% while adjusted concentrations in smallmouth bass fillets remained essentially unchanged or may have increased. Conversely, at Battle Creek, adjusted PCB concentrations in carp fillets were unchanged from 1987 through 2001, while concentrations in smallmouth Bass were declining at a 9- to 10% annualized rate. PCB concentrations in smallmouth bass at Mosel Avenue have apparently not changed since 1993. At Plainwell Impoundment, PCB concentration declines in carp fillets have slowed from a 5.8% average annualized rate from 1983 through 2001, to a 4.6% rate in the 1990s through 2001. While these changes in decay rate are relatively small, they may translate into fairly large differences in the time required to attain remedial objectives. Assuming that PCB concentration will decay exponentially in the future may result in overly optimistic projections of the performance of natural attenuation as a remedial alternative.

4.3 Current and Future Exposure to Fish Consumers

In 2001, fish consumers could expect an average exposure of 2- to 4- mg/kg wet-weight PCB from carp fillets at Plainwell, Otsego City, Otsego and Trowbridge and Allegan City Impoundments and in the Kalamazoo River near New Richmond (Figure 1). These concentrations are at levels that would trigger MDCH no-consumption advisories for all potential consumers

The expected average exposures at Lake Allegan and Saugatuck were somewhat lower, (0.7- and 1.2-mg/kg respectively) but at levels that would trigger some form of consumption advisory. All concentrations were greater than the MDCH risk based cleanup goal (0.12 mg/kg) protective of central tendency sport anglers.

Fillet PCB concentration adjusted to ABSA-specific average length and lipid levels are an indicator of the long-term exposure that fish consumers could expect from eating fish from a particular ABSA. These adjusted data incorporate the exposures that fish are receiving as well as accounting for differences in the historic distribution of length and lipid among ABSA. For example, since the 1980s carp collected form Lake Allegan have historically been smaller and have had lower lipid levels than at Plainwell Impoundment. So, although carp are exposed to similar concentrations of environmental PCB at both ABSA, fish consumers could expect higher long-term exposures of PCB from Plainwell Impoundment than from Lake Allegan because fish consumers can expect to catch larger carp with higher lipid levels at Plainwell.

PCB concentrations in fish tissues are a function of concentration in water, sediment and prey, lipid content and exposure duration. Although current PCB concentrations in Lake Allegan carp are lower than at surrounding ABSA (New Richmond and Allegan city Dam) this is primarily due to differences in lipid and length distributions. If changes in environmental conditions or fisheries management practices were to induce an increase in the lipid fraction in carp at Lake Allegan, PCB concentrations would be expected to increase to levels similar to those at other ABSA within the superfund site.

Estimated long-term exposure to PCB for consumers of smallmouth bass in 2001 was lower than that for consumers of carp. Exposures at ABSA within the superfund site in 2001 are estimated to range from 0.5- to 1-mg/kg, while those at Battle Creek and Morrow Pond are estimated to be approximately 0.03- and 0.09-mg/kg respectively (and Figure 1).

With the exception of Lake Allegan, PCB concentration in carp fillets from ABSAs within the superfund site are expected to range from approximately 0.6- to 3.0-mg/kg in 2020 (Figure 2). These predictions are precise to approximately one order of magnitude. The difference between no-consumption and limited-consumption criteria is approximately one order of magnitude, so it is difficult to predict whether consumption advisory limits for carp would be lifted by 2020. Average PCB concentrations in carp fillets at Lake Allegan are expected to range from less than 0.01 to approximately 0.3 mg/kg.

Under existing conditions, PCB concentrations in smallmouth bass fillets from ABSA within the superfund site are expected to range from approximately 0.1- to 1.0 mg/kg in 2020. As with PCB concentrations in carp fillets, PCB concentrations in smallmouth bass fillets at Lake Allegan are expected to be lower than at other ABSA, ranging from 0.006- to 0.2-mg/kg.

These predictions are based on the assumption that the MO model is appropriate for evaluating these data. At most ABSAs, the MO model and first order decay models fit the data equally well. At some ABSAs we reject the hypothesis of exponential decay. For the most part, the decay rate of the best MO declined with time, but differences from exponential decay were not statistically significant. This suggests that PCB decay rates in carp and smallmouth bass fillets cannot be expected to continue at rates observed in the 1980s and early 1990s. In general, existing data are not adequate to precisely determine the rate at which PCB concentrations will decay in the near future. The rapid decay rates observed from the early 1980s to 1990 tend to dominate estimates of future decay rates. More recent data suggest that decay rates are beginning to slow, although the currently available temporal record is not adequate to precisely estimate the degree to which decay rates may be changing.

Based on the existing data it is likely that, at most ABSA, some form of consumption advisory will continue through 2020 for carp. In particular, concentrations are most likely to remain elevated at Plainwell, Otsego City, Otsego, Trowbridge and Allegan City Impoundments.

4.4 Comparison of Wet-weight PCB Concentrations to Advisory Criteria

The MDCH sets fish consumption advisories based on wet-weight fillet concentrations. Following is a comparison of wet-weight PCB concentrations with MDCH advisory criteria. Wet-weight PCB concentrations in carp from throughout the superfund site are currently at levels that would trigger some form of consumption advisory. At the three former impoundments (Plainwell, Otsego and Trowbridge) wet-weight PCB concentrations are at levels that would trigger a no-consumption advisory.

Upstream of the superfund site, (Battle Creek, Morrow Pond and Monarch Mill Pond) PCB concentrations are at levels where the general population could be permitted unlimited consumption. At these same sites, wet-weight concentrations are such that women and children would be restricted to one-meal-per-month with the exception of Monarch Mill Pond where women and children could eat one meal per week.

At all ABSAs including those up stream of the superfund site, wet-weight PCB concentration in carp fillets are above the risk-based 0.11 mg/kg MDEQ cleanup goal protective of central tendency sport anglers. Wet-weight PCB concentration in smallmouth bass fillets in 1999, 2000 and 2001 are sufficiently low that general-population consumption advisories would not be triggered at any ABSA.

For women and children, unlimited consumption of smallmouth bass fillets could be permitted at Battle Creek, but some form of advisory would be triggered at all other ABSA. At all sites except Battle Creek, Average Wet-weight PCB concentration in smallmouth bass were higher than the risk-based 0.11 mg/kg MDEQ cleanup goal designed to be protective of central tendency sport anglers.

4.5 Lake Allegan vs. Other Sites

With the exception of Lake Allegan and the St. Joe River, PCB concentrations in whole-body carp from inland-rivers were generally lower than those from great-lakes and connecting waters. PCB concentrations in whole-body carp from Lake Allegan (4.8 mg/kg) were greater than or equal to those found at any site in the State of Michigan, other than Lake Erie (6.1 mg/kg). Whole-body carp from Lake Allegan had significantly higher PCB concentrations than those from 3 of 4 inland sites studied, (Raisin, Grand and Muskegon Rivers) and 3 of the 7 great lakes sites studied (Lake St. Clair, Munuscong Bay, Thunder Bay; $p<0.05$). PCB concentrations in whole-body carp from the St. Joe River, in southwestern Michigan, were similar to those at Lake Allegan (Figure 3).

PCB concentrations in whole-body carp from Lake Allegan were similar to those at Lake Erie, Grand Traverse Bay, the Detroit River, Saginaw Bay and the St. Joe River. With the exception of Grand Traverse Bay, these sites receive effluent from some of the most heavily industrialized areas in Michigan.

After adjusting for variation in length and lipid-content, geometric mean PCB concentration in whole-body carp from Lake Allegan (4.75 mg/kg) was exceeded only by that from Lake Erie (6.1 mg/kg).

4.6 Interim Removal Action at Former Bryant Mill Pond

There has been considerable debate about the potential for environmental dredging to produce short- or even long-term reductions in fish tissue contaminant concentrations. However, the majority of sediment removal actions cited by General Electric involved removal of localized hot-spots which may have only minimally impacted the overall average concentrations to which biota are exposed. However, a remedial action conducted in Sweden included dredging of expansive areas of Lake Jarnsjon resulting in post remedial average sediment concentrations below 1.0 mg/kg. At that site, follow-up studies of fish tissue concentrations indicated that PCB concentrations had declined in the first year after the remediation, although reductions could not be separated from that expected through natural attenuation.

At Former Bryant Mill Pond on Portage Creek, a similar approach was taken in that nearly all known PCB containing sediments were removed from the currently and formerly impounded areas area rather than attempting to isolate and remove individual hotspots. Carp were sampled both before and after the removal action, and post removal concentrations are substantially lower than would have been expected under natural attenuation (Figure 4). Under a no action alternative, concentrations at Bryant Mill Pond are predicted to have been around 1.0 mg/kg in 2020. In 2000 and 2001, after the (1998/1999) removal action, Carp fillet concentrations averaged 0.3 mg/kg and 0.4 mg/kg respectively. This suggests that the removal action may have accelerated recovery by over 20 years relative to natural attenuation. These data support the hypothesis that environmental dredging can be successful when contaminant deposits are properly delineated and a conservative approach is used to identify and remove potentially contaminated sediments.

FIGURE 1.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED (SITE-WIDE) PCB CONCENTRATION
IN COMMON CARP AND SMALLMOUTH BASS FILLETS IN 2001
INDEX TO EXPOSURE THAT FISH RECEIVE

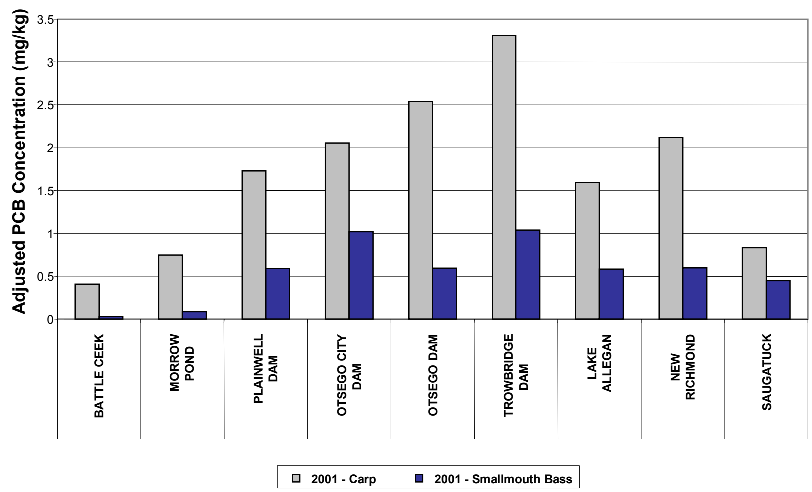
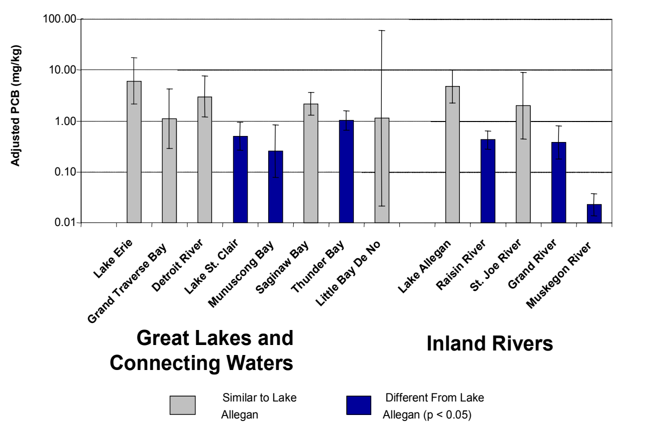


FIGURE 2.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED PCB CONCENTRATION IN WHOLE BODY CARP
AT TREND MONITORING STATIONS WITHIN THE STATE OF MICHIGAN

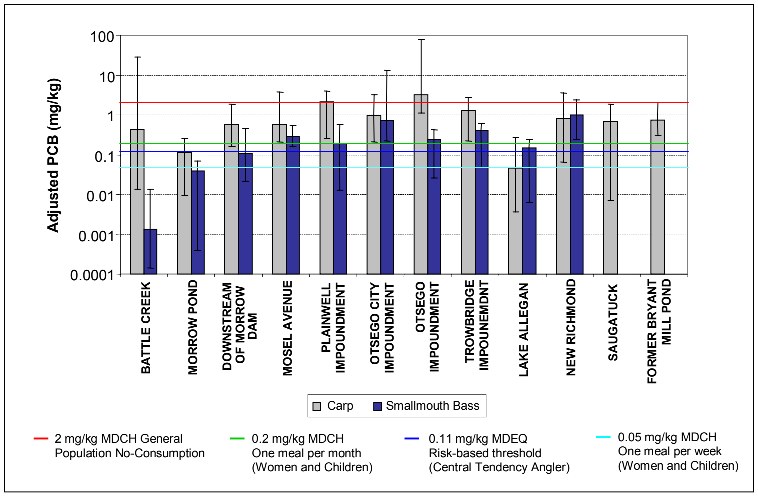


Notes:
1. Bars represent mean length- and lipid-adjusted PCB concentration in whole body carp.
2. Error bars represent 95% confidence limits.
3. White bars represent mean adjusted PCB concentrations that are significantly less than the mean concentration at Lake Allegan at the 5% significance level using Duncan's multiple comparison procedure.

FIGURE 3.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PROJECTED PCB CONCENTRATION IN CARP AND SMALLMOUTH BASS FILLETS IN 2020

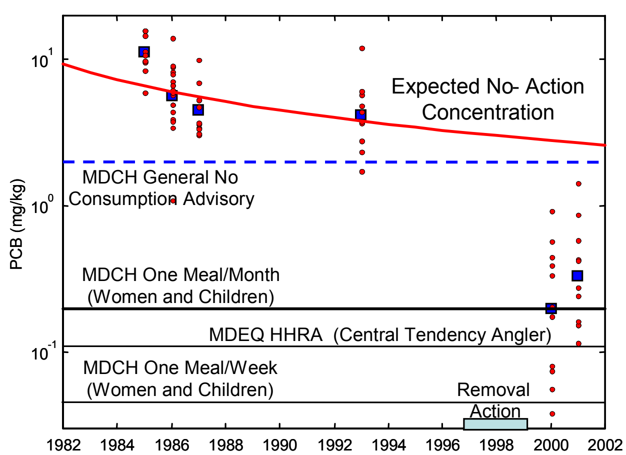


Notes:
1) Projectied concentrations for Bryant Mill Pond are based on data collected prior to the removal action in 1999 and reflect what would have been expected had the removal not been conducted.
2) Bars represent the best fit MO temporal trend model for the mean, and error bars represent 95% bootstrap confidence intervals..

FIGURE 4.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PERFORMANCE OF INTERIM REMOVAL ACTION AT FORMER BRYANT MILL POND



Notes:
1. Red line represents forecasted no-action alternative.

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Section 1
Introduction

The Kalamazoo River drains an approximately 2000-square-mile watershed including nearly 400 miles of tributaries in Southwest Michigan. The lower approximately 80 miles of the river are part of the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. Portage Creek is a tributary joining the Kalamazoo River at Kalamazoo, Michigan, the lower three miles of which are also included in the Site. The presence of polychlorinated biphenyls (PCB) was first reported in the Kalamazoo River and biota of the river in 1971. This consequently resulted in consumption advisories for fish from the Kalamazoo River and Portage Creek. Several subsequent studies have documented the presence of PCB within the surface water, sediments, floodplain soil, and biota of both the Kalamazoo River and Portage Creek, as well as in landfills adjacent to both surface water bodies. In an effort to monitor human-health and ecological risk on the river system, samples of common carp (*Cyprinus carpio*), smallmouth bass (*Micropterus dolomieui*), and a variety of other species have been collected at 17 sites within the Kalamazoo River and Portage Creek.

Assessment of the effectiveness of remedial alternatives on the Kalamazoo River system requires evaluation of future risks to human and ecological health, and quantification of uncertainty in those predictions. Risks result from contact between ecological and human receptors that are of sufficiently long duration and of sufficient intensity to elicit adverse effects (EPA 1992). In this region, human health risks from chlorinated organic compounds such as PCB are primarily associated with ingestion of contaminated fish tissue (Birmingham, et al. 1989; Newhook, et al. 1988; Fitzgerald, et al. 1996). At all superfund sites, a no-action alternative must be evaluated and is the basis to which the cost-effectiveness of other alternatives is compared; this requires an understanding of the likely effect of no action. Among other indices, the National research council (NRC 2001) recommends PCB concentration in fish tissue as an indicator of remedial performance. Therefore, estimates of current and future fish-tissue concentrations are necessary in order to provide a baseline against which other alternatives can be compared. An estimate of uncertainty in these predictions is necessary in order to determine the adequacy of available data to compare competing alternatives.

Temporal trends in the mean or median PCB concentration in fish tissue are typically nonlinear and often modeled as a first order decay process (exponential decay). Stow et al. (1999) pointed out that the first order assumption requires that concentrations decay to zero at a constant rate, precluding the possibility that decay rates may change with time, (or achieve a near steady state nonzero equilibrium). In an effort to correct this weakness, they considered two models for the median PCB concentration in fish tissue; a first order decay model with nonzero asymptote (NZA) and a mixed order model (MO).

$$C_{NZA}(t) = C_F + C_0 \cdot e^{-k\cdot(t-t_0)}; \quad \textit{First Order Decay}$$

$$C_{MO}(t) = \left[C_P{}^{\theta} - k \cdot (t - t_P) \cdot (\theta)\right]^{\frac{1}{(\theta)}}; \quad \textit{Mixed Order Model}$$

The MO model is the solution to the differential equation $dC / dt = kC^{1-\theta}$. Note that when $\theta = 0$ the MO model reduces to first order decay. Although the MO model offers more flexibility than first order decay, model fitting and statistical inferences require more sophisticated methods. Standard least squares and maximum likelihood methods for prediction and quantification of uncertainty cannot be applied to this model because it is neither log-linearizable (Neter et al 1996), nor in the class of generalized linear models (McCullagh and Nelder, 1989) for which substantial theory and application has been developed. Stow, et al. used non-linear least squares to fit the model to their data and to estimate approximate confidence limits. Following Stow, we use the mixed-order model for the decay rate of PCB concentrations in fish tissue samples taken from the Kalamazoo River, but we found nonlinear least squares methods to be inadequate because matrices, required to quantifying uncertainty, were ill-conditioned (Kennedy and Gentle, 1980, p. 34). Profile likelihood methods have been suggested to avoid these numerical instabilities, although, in this instance, we found that profile likelihood tended to underestimate uncertainty in predicted fish tissue concentrations (Goff, Unpublished Data; 2002). As an alternative to non-linear least squares and profile likelihood, we used bootstrap resampling (Efron and Tibshirani, 1986) to estimate uncertainty in modeled estimates of mean PCB concentration in carp and smallmouth bass fillets. Models were fit to data from 13 aquatic biota study areas (ABSA(s)) along the Kalamazoo River and Portage Creek where sample sizes were adequate to estimate temporal trends in concentration.

When analyzing lipophilic contaminants such as PCBs, wet-weight concentrations are often normalized by dividing by the percentage of the sample composed of lipids (ratio method). This lipid normalizing by the ratio method is thought to eliminate the influence of lipid covariation. Hebert and Keenleyside (1995) point out that lipid normalization using ratios may be inappropriate when the relationship between lipids and contaminant concentration cannot be described by a linear regression through the origin. They propose an alternative approach using analysis of covariance (ANCOVA; Neter et al., 1996) both to decide when normalization is appropriate, and to conduct the normalization. We also found that length was sometimes an important predictor of PCB concentrations in fish fillets, so we used a modification of Hebert and Keenleysides approach to simultaneously adjust PCB concentration for covariation with fish-length and fillet lipid-content. Failure to adjust for these potentially confounding factors could lead to misinterpretation of perceived temporal trends due to differences in lipid and or length distributions among years. Because lipid/length associations with PCB varied among years, the data were analyzed in a two stage process where: 1) wet-weight PCB concentrations were adjusted for differential lipid and length within species, ABSA and year combinations; and 2) the mean of these adjusted concentrations was modeled as a MO model in time. Uncertainty in estimates based on this two stage fitting method was quantified using bootstrap re-sampling (Efron and Tibshirani, 1986).

Section 2
Objectives and Rationale

2.1 Objectives

The primary objectives of this report are to: (1) quantify current PCB concentrations in carp and smallmouth bass fillets; (2) describe spatial and recent temporal trends in PCB concentration in carp and smallmouth bass fillets; and (3) describe near future trends in PCB concentration through 2020.

2.2 Rationale

The Kalamazoo River Study Group (KRSG) has used temporal trends in PCB concentration in fish tissue samples from Lake Allegan and Plainwell impoundment to support their hypothesis that natural recovery may be a viable remedial alternative for the Kalamazoo River. KRSG has expressed these temporal trends in terms of half-times which are based on the assumption of a first order decay model. These first-order concentration forecasts require that future PCB concentrations continue to decay at the same average rate that has been observed since the early 1980s. While recent fillet-PCB concentrations are lower than those in the early to mid 1980s, these declines may be due to a combination of factors including: (1) restrictions on manufacture and discharge of PCBs into the environment; (2) active control of PCB sources to the river and; (3) natural recovery. Similar temporal trends have been observed at the Hudson, Fox and Saginaw rivers (NRC, 2001; pp. 201-205) Data collected more recently at some sites suggests that current PCB concentrations at the site may be higher than exponential decay rates would have predicted. Stow et al (1999) noted that decay rates in PCB concentration in salmonids in Lake Michigan were slower in the 1990s than would have been expected under the first order decay assumption. Stow et al. (1999) proposed the mixed order model (MO) as a more flexible alternative to first order models for forecasting near-term temporal trends in PCB concentration. Stow also discussed a first order decay model with nonzero asymptote to estimate trends when decay rates are not constant. They rejected the NZA model due to the unrealistic assumption that PCB concentrations would be required to remain above some non-zero equilibrium concentration indefinitely. Two phase regression models (e.g. spline-regression; Larson, 1992) were also used to model time varying decay rates in fish from the Fox River (Thermo Retec 2001). These two-phase regression models require the assumption of a discrete temporal change-point. Because reduction in PCB sources to most environmental sites have occurred gradually over time (i.e. source reduction and removal actions), the existence of a discrete change-point may not be appropriate. An advantage of the MO time-varying decay rate is that neither an arbitrary change point, nor a perpetually fixed nonzero asymptote is required. Because the first order decay model is a special case, the MO, also provides a framework to test the null hypothesis of first order decay.

Section 3
Methods

3.1 Field Sampling Methods

Common carp and smallmouth bass were collected by the State of Michigan, Blasland Bouck and Lee, Inc., and Camp Dresser and McKee, Inc. by electro-shocking at 17 sites, 15 along the Kalamazoo River and 2 along Portage Creek (Figure 1). Approximately 11 fish of each of the 2 species were collected at a selected subset of sites each year. Some sites were sampled more frequently than others, dependent upon particular monitoring objectives each year. Species other than common carp and smallmouth bass were occasionally caught and retained for analysis. Data associated with each species are summarized in tabular form. Temporal trend analyses that are discussed in the following sections are based on all data collected in these studies. Fish fillet data representing edible portions are collected primarily to evaluate potential exposure of and risk to human consumers. Whole body samples may be more appropriate for analysis of temporal trends, however, due to the limited availability of such samples, temporal trends were estimated using fillet data.

Length and weight were measured and recorded for each fish and the fillets were frozen and delivered to analytical laboratories for analysis of percent lipid and total PCB concentration. The skin was removed from carp fillets and left on smallmouth bass fillets. The resulting data are summarized by site, species, year, and study in Table 1. Length, weight, lipid-fraction, and condition-factor (mass per length cubed) and PCB concentration are plotted in Figures (2) through (7).

3.2 Statistical Methods

PCB concentration in carp and bass fillets was tested for significant covariation with lipid, length, weight, and body condition. PCB concentrations were adjusted for covariation with these factors using multiple regression. To avoid the effects of multicollinearity, lipid-fraction, length, weight, and body condition were also tested pair-wise for correlation and pairs of correlated factors were not included in multiple regression models. These adjusted data were used to estimate temporal trends using the MO model, and uncertainty was estimated using a bootstrapping algorithm (Efron and Tibshirani 1986). This report documents temporal trends in PCB concentration in common carp and smallmouth bass fillets (i.e., edible portions).

3.2.1 Adjusted PCB Concentration

Bioaccumulation of PCBs in organisms is expected to be strongly associated with the lipid-fraction (Landrum and Fisher, 1999). PCB accumulation rates and concentrations may also vary with age and condition of organisms due to changes in dietary loads as well as dilution effects related to fish growth. Because inter-annual variation in length, lipid, weight, and condition (K%mass/Length^3) could bias and or confound perceived temporal trends in PCB concentration, we adjusted PCB concentration for these factors when effects were found to be statistically significant at the 0.05 level of significance. Factors that were significant predictors of PCB concentration, and not inter-correlated were included in final models.

Fillet data were adjusted in two ways:

1) based on overall site-wide average lipid; and

2) based on ABSA-specific average lipid and length.

Adjustment method (1) is appropriate to compare exposure of fish to PCBs (the exposure that fish receive). These adjusted concentrations are appropriate for comparing PCB concentrations and attenuation rates among ABSA and years.

Adjustment method (2) provides an estimate of the exposure that human fish consumers would expect to receive on average. These adjusted concentrations are appropriate for temporal comparison of PCB concentrations within ABSA. They can also be used to calculate the expected exposure associated with fish consumption. Adjusted concentrations based on methods (1) and (2) are similar for ABSA where the length/lipid distribution is similar to the population as a whole. If the lipid/length distribution varies significantly from the overall distribution, adjustment methods (1) and (2) will tend to differ.

Because of the well documented dependence between lipophilic contaminants such as PCB and lipid content, we first tested for a significant correlation between PCB concentration and lipid content before testing for other effects. To avoid the effects of multi-collinearity (Neter et al 1996), weight and body condition were not included in the regression models. PCB-Lipid-length relationships were represented as the log linear model

$$\log(C_k) = \beta_0 + \beta_1 \times \log(Lipid_k) + \sum_{i=2}^{p+1} \beta_i \times (year_{ik}) + \sum_{j=p+2}^{2p+1} \beta_j \times \log(Lipid_k) \times (year_{jk})$$

$$+ \beta_{2p+2} \times \log(length_k) + \sum_{j=2p+3}^{3p+2} \beta_j \times \log(Length_k) \times (year_{jk}) + \varepsilon_k \qquad (1)$$

$$k = 1,2,3 \ldots n$$

where C_k represents tissue PCB concentration in the k^{th} fish, $year_{ik}$ is a discrete indicator variable equal to 1 in the i^{th} year and 0 otherwise, $lipid_k$ and $length_k$ represent the lipid content and length of the k^{th} fish respectively.

This model amounts to fitting a multiple linear regression between the natural log of concentration and the natural log of lipid and length, within each year, ABSA and species combination. In situations where the regression is through the origin, and the length effect is not significant, this is analogous to lipid normalizing using the ratio method (i.e. dividing each PCB concentration by the corresponding lipid fraction; Hebert and Keenleyside 1994).

Predictors that were found to be significant were used to adjust wet-weight PCB concentration in two ways: (1) based on long term averages for data pooled across all ABSA; and (2) based on long term averages within each ABSA. The adjusted data were calculated as follows.

Equation (1) can be rewritten in matrix form as $\mathbf{C} = Exp(\mathbf{X\beta}) \times \boldsymbol{\varepsilon}'$ where X is the design matrix containing the year effects and lipid and length effects found to be significant at the 0.05 level, **$** is the vector of regression coefficients estimated by linear least squares (Neter et al 1996), and $\boldsymbol{\varepsilon}'$ is a vector of lognormally distributed errors with mean 1 and variance F. Define $\mathbf{R} = \log(\mathbf{C}) - \mathbf{X}\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\beta}}$ to be the vector of residuals and estimated regression coefficients respectively. Also define $\mathbf{X}_{rep}$ to be a vector containing the lipid and length measurements for a representative fish. For adjustment method (1) $\mathbf{X}_{rep}$ contained the mean length and lipid (natural log scale) for all fish of a particular species averaged over all years and ABSA (site-wide). For adjustment method (2) $\mathbf{X}_{rep}$ contained the mean length and lipid (natural log scale) for fish of a particular species averaged over all years within each ABSA. The vector of adjusted PCB concentration is $\mathbf{C}_{adjusted} = \exp(R + \mathbf{X}_{rep}\hat{\boldsymbol{\beta}})$.

3.2.2 Spatial Trends

Adjusted PCB concentrations were summarized for each ABSA in Table 1. Average site-wide adjusted concentrations were also plotted for each year for Battle Creek, Plainwell Impoundment, Lake Allegan and New Richmond.

3.2.3 Temporal Trends

We fit the MO model to the adjusted PCB concentrations $\mathbf{C}(t)_{adjusted} = MO(t)$, estimating the parameters by maximum likelihood assuming a lognormal error. The overall model is of the form $C(t) = e^{\mathbf{X\beta}} MO(t)\varepsilon'$. We used this two stage fitting process to allow the coefficients on lipid and length to vary with year within each ABSA. The variance and confidence limits of parameter estimates and future predictions was estimated using a bootstrapping algorithm where fish were resampled with replacement within each species, ABSA and year combination. One thousand bootstrap samples were drawn for each species, ABSA combination. Fitted models, estimated means and confidence limits were plotted for carp and smallmouth bass for each ABSA. The MO model was used to project future concentrations with confidence limits from 2002 through 2020. Projections were estimated based on all data (Model I) as well as a subset of data restricted to post-1990 samples (Model II) to evaluate the sensitivity of projections to samples collected in the 1980s. Finally, first order decay models were also fit to the adjusted data, and the half-time and confidence limits were estimated and plotted.

3.2.4 Comparison of Lake Allegan and Other State Sites

We compared length- and lipid-adjusted PCB concentration in whole-body carp samples from Lake Allegan with whole body carp samples from 7 trend monitoring sites on great lakes and connecting waterways and 4 sites on inland rivers. Like the Lake Allegan, each of the inland river sites was located upstream of the dam closest to each rivers confluence with a great lake. This excluded fish that could have migrated from the great lakes, where PCB concentrations are often higher than in inland waterways (Personal communication, Robert Day). The great lakes sites included Lake Erie, Grand Traverse Bay, Detroit River, Lake St. Clair, Munuscong Bay, Saginaw Bay, and Thunder Bay. The inland sites included the Raisin, St. Joe, Grand and Muskegon Rivers. Adjusted PCB concentrations were compared using Dunnett's procedure (Dunnett 1955) for comparing several means to a single control. Dunnett's procedure was used to control the maximum experimentwise Type I error rate at the 5% significance level. Type I errors occur when the null hypothesis of no difference among sites is not rejected when in fact a difference actually exists. Because sites were not sampled every year, data were from 1997, 1998 and 1999 were combined for analysis.

Section 4
Results

4.1 General Results

At most sites, wet-weight PCB concentrations in carp and smallmouth bass fillets were lower in 2000/2001 than in the mid to late 1980s.

Average adjusted PCB concentrations were summarized in Table (1) in 4 ways. Data were adjusted using ABSA-specific average length and lipid and site-wide average length and lipid, and adjustments were applied based on fish collected from 1983-2001 (Model I) and those collected from 1990 through 2001 (Model II). Site-wide adjusted PCB concentrations for Model I were plotted in Figure (8). These adjusted data indicate the PCB concentration to which fish are exposed, and are appropriate for comparing site conditions among ABSA and years. Recall each ABSA is a discrete river segment typically bounded by dams which reduce migration of fish among ABSAs. Fish collected from most ABSAs can be considered indicators of conditions in each of these discrete river segments.

Site-wide and ABSA-specific length- and lipid-adjusted PCB concentrations for Model I are plotted for Carp and Smallmouth Bass in 2001 in Figures (9) and (10) respectively. These concentrations represent the expected bioaccumulation of fish and the expected exposure to fish consumers respectively in 2001. Fitted models (Model I and Model II) are plotted for each ABSA-Species combination in Figures (11) through (32).

Wet-weight PCB concentration in fillets is representative of the exposure a fish consumer would have received from a particular cohort of fish in a particular year. However, to apply this information to risk assessment the consumers "expected" exposure over a period of years may be more important. To estimate this expected exposure for fish from each ABSA, PCB concentration was adjusted to be representative of a fish with average length and lipid-fraction. Provided that length and lipid distributions remain stable over long periods of time, these adjusted concentrations are representative of long-term exposures that fish consumers would be expected to receive. Following is a summary of wet-weight and ABSA-specific adjusted PCB concentration for carp and smallmouth bass fillets from the Kalamazoo River and Portage Creek.

Average wet-weight and lipid- and length-adjusted PCB concentrations in carp and smallmouth bass fillets continue to be higher at ABSAs within the superfund site than at Battle Creek. Currently (2001) wet-weight PCB concentrations average 0.40 mg/kg in carp and 0.06 mg/kg in smallmouth bass at Battle Creek. At ABSAs within the superfund site, average wet-weight concentration in carp fillets ranges from 1.49 mg/kg at Lake Allegan to 9.80 mg/kg at Plainwell Impoundment. PCB concentration in smallmouth bass fillets at ABSA within the superfund site range from 0.46 mg/kg at Otsego City Impoundment to 1.20 mg/kg at Trowbridge Impoundment. In general, PCB concentration in carp and smallmouth bass fillets from ABSA within the superfund site remain 1 to 2 orders of magnitude higher than those from the reference area, Battle Creek.

Lipid, length and weight distributions of fish collected from the ABSAs were found to vary temporally, although trends were not consistent among ABSAs (Figures 2 through 5). For example, lipid, length and weight in carp increased from the 1980s through 2001 at Plainwell Impoundment, while these same metrics decreased at New Richmond. Temporal trends in body condition also varied among sites. Condition of carp and smallmouth bass at Battle Creek increased over the period of study while body condition in carp and smallmouth bass decreased at New Richmond.

PCB concentration and percent lipid were correlated at all ABSAs, while association between PCB concentration and length varied by ABSA. For example, at Lake Allegan, carp fillet PCB concentration tracks fluctuations in lipid fraction, while association with length is less consistent (Figure 7). Because PCB concentration is associated with spatially and temporally variable lipid-fraction and, at times, fish-length, spatial and temporal comparisons, and temporal projections should be based on lipid and/or length adjusted PCB concentrations. The following sections describe analysis of spatial and temporal trends in adjusted fillet-PCB concentration.

4.2 Lipid and Length Adjustments

PCB concentration was correlated with lipid-fraction ($p < 0.05$) in both Carp and Smallmouth Bass fillets at all sites where trends were estimated (Table 2). Additionally, after adjusting for covariation with lipid-fraction, PCB concentration in carp fillets was correlated with fish-length ($p<0.05$) at Morrow Pond, Plainwell Impoundment, Otsego City Impoundment and Saugatuck. After Adjusting for covariation with lipid-fraction, PCB concentration in smallmouth bass fillets was correlated with fish-length ($p<0.05$) at Battle Creek, Plainwell Impoundment and Saugatuck.

A summary of estimated regression coefficients can be found in Table (3). The reported significance levels are based on the conditional test procedure described by Neter et al (1996). When year-by-lipid or year-by-length interactions were statistically significant, the corresponding main effects were retained in the model, so the statistical significance of those effects is not reported. These regression relationships were used to adjust wet-weight PCB concentration.

4.3 Expected Exposure for Fish Consumers

The Michigan Department of Community Health (MDCH) has established criteria for placing fish on the Michigan Sport Fish consumption Advisory. The criteria for the general population differ from that for sensitive populations -- women of childbearing age and children under 15 years of age).

General Population

For the general population, when between 11 and 49 percent of samples exceed 2 mg/kg in fish, a one-meal/week advisory is issued; when greater than 50 percent of fish samples exceed 2 mg/kg, a no consumption advisory is issued.

Sensitive Population

For women of childbearing age and children under 15 years of age, at concentrations greater than 0.05 mg/kg up to 0.2 mg/kg of PCBs in fish, a one-meal /week advisory is issued. At concentrations greater than 0.2 mg/kg, up to 1 mg/kg of PCBs in fish, a one-meal/month advisory is issued. At concentrations greater than 1.0 mg/kg up to 1.9 mg/kg in fish, a six-meal/year advisory is issued. At concentrations above 1.9 mg/kg, a no consumption advisory is issued.

Risk Based Cleanup Goal

The MDEQ has also established 0.11 mg/kg PCBs in fish as a cleanup goal protective of central tendency anglers. In the following sections observed PCB concentrations are compared with these MDCH criteria and the MDEQ risk based cleanup goal. For comparative purposes, the MDCH 2-, 0.2-, and 0.05-mg/kg criteria and the 0.11-mg/kg cleanup goal are indicated on Figures (11) through (33) with horizontal lines.

4.3.1 Battle Creek

Carp

Since 1987, PCB concentration in fillets ranged from a minimum of less than detection limits (approximately 0.05 mg/kg) to a maximum of 1.2 mg/kg. Over this same period, average wet-weight fillet PCB concentration ranged from 0.08 to 0.4. In all years, average and maximum PCB concentrations were below the 2 mg/kg Michigan Department of Community Health general consumption advisory limit. In all but 2 years (1991 and 2001) average concentration was below the 0.2 mg/kg MDCH advisory level of one-meal-per-month for women and children. Average wet-weight concentrations exceeded the MDEQ 0.11 mg/kg risk-based cleanup goal protective of central tendency sport anglers (CDM 2001) in 1987, 1991, 2000 and 2001.

Adjusted PCB concentration in carp fillets was sometimes higher and sometimes lower than wet-weight concentration depending on the lipid and length of individual fish. As with wet-weight PCB concentrations, average adjusted PCB concentrations never exceeded the 2 mg/kg MDCH general consumption advisory level. Adjusted concentrations exceeded the 0.2 mg/kg MDCH advisory level for women and children and the MDEQ HHRA tendency angler level in 1991 (0.67 mg/kg) and 2001

(0.41 mg/kg). Average adjusted PCB concentration also exceeded central tendency sport angler limit in 1997 (0.19 mg/kg).

Smallmouth Bass
Since 1997, wet-weight PCB concentration in individual smallmouth bass fillets never exceeded any of the MDCH criteria nor the risk-based-cleanup goals Average wet-weight PCB concentration slightly exceeded the MDEQ risk-based level for the central tendency angler (0.11 mg/kg) in 1993 (0.13 mg/kg). After adjusting for covariation with lipid and length, average adjusted PCB concentration in smallmouth bass fillets never exceeded the MDCH general consumption-, one-meal-per-month for women and children-criteria, nor the MDEQ risk-based cleanup goal for the central tendency anglers.

4.3.2 Morrow Pond

Carp
Since 1985, PCB concentration in fillets ranged from a minimum of 0.06 in 1997 to a maximum of 12.7 mg/kg in 1986. Over this same period, average wet-weight fillet PCB concentration ranged from 0.22 in 1999 (LTM sampling) to 3.46 in 1986. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in 1985 and 1986. Average wet-weight PCB concentration exceeded the 0.2 mg/kg MDCH advisory level of one-meal-per-month for women and children and the 0.11 mg/kg risk-based cleanup goal protective of central tendency sport anglers in every year sampled from 1985 through 2001.

Average adjusted PCB concentration ranged from 0.25 mg/kg in 1999 to 3.33 mg/kg in 1986. As with wet-weight concentrations, adjusted average concentrations also exceeded the 0.2 mg/kg MDCH advisory level of one-meal-per-month for women and children and the 0.11 mg/kg risk-based cleanup goal protective of central tendency sport anglers in every year sampled from 1985 through 2001.

Smallmouth Bass
Wet-weight PCB concentration in individual fish ranged from a minimum of 0.03 mg/kg in 1997 to a maximum of 1.44 mg/kg in 1985. Average wet-weight PCB concentration never exceeded the 2 mg/kg MDCH general consumption advisory level, but exceeded the MDEQ risk based central tendency angler cleanup goal of 0.11 mg/kg in 1985 through 1999. Average wet weight PCB concentrations have been slightly below the 0.2 mg/kg MDCH-criteria since 1993. Average PCB concentration in 2001 (0.07 mg/kg) was below the MDEQ risk based cleanup goal of 0.11 mg/kg.

Average adjusted concentrations ranged from 0.09 in 2001 to 1.17 in 1985. Average adjusted concentrations exceeded the MDEQ risk-based cleanup goal in 1993 through 1999, but were below the MDCH advisory limit for one-meal-per-month for women and children (0.20 mg/kg). As with wet-weight concentrations, average adjusted PCB concentration (0.09 mg/kg) was below the 0.11 mg/kg MDEQ risk-based limit in 2001.

Other Species
One channel catfish (*Ictalurus punctatus*) captured in 2001, had 0.34 mg/kg wet-weight PCB concentration, exceeding the 0.2 mg/kg criteria. Three largemouth bass (*Micropterus salmoides*) were captured in 1985, had wet-weight PCB concentration ranging from 1.16-, to 1.95-, averaging 1.55-mg/kg.

4.3.3 Downstream of Morrow Dam

Carp
The area from Morrow Dam to the confluence of Portage Creek and the Kalamazoo River was sampled in 1993 by KRSG and in 2000 by MDEQ as part of the LTM. The area was sampled in 2001 as part of the LTM, but no carp were captured. Eleven carp were caught in 1993 with PCB concentration ranging from 1.3 mg/kg in 2001 to 8.2 mg/kg in 1993. Average PCB concentration was 2.95 mg/kg in 2000 and 4.43 mg/kg in 1993. These PCB levels exceed the general consumption advisory level of 2.0 mg/kg.

Average adjusted PCB concentrations were similar to wet-weight concentrations, 2.38 mg/kg in 2000 and 4.69 mg/kg in 1993.

Smallmouth Bass
Eleven smallmouth bass were caught in both 1993 and 2000, and 1 additional fish was caught in 2001. Wet-weight PCB concentration ranged from a minimum of 0.06 mg/kg in 2000 to 3.23 mg/kg in 1993. Average wet-weight PCB concentration was 0.25 mg/kg in 2000 and 1.09 mg/kg in 1993, an apparent 4 fold reduction in wet-weight PCB concentration.

Average adjusted PCB concentration was less variable, ranging from 0.39 mg/kg in 2000 to 0.61 mg/kg in 1993, an approximate 36% reduction. This indicates that much of the 4-fold reduction in wet weight concentration was due to variation in length and lipid. Average adjusted PCB concentrations were below the MDCH general consumption advisory but above the MDCH advisory for women and children, and the MDEQ risk-based advisory levels.

Other Species
One northern pike (*Esox, lucius*) and one rock bass (*Ambloplites, rupestris*) were captured with wet-weight PCB concentrations of 0.43- and 0.05-mg/kg respectively.

4.3.4 Mosel Avenue

Carp
Wet-weight PCB concentration in fillets ranged from a minimum of 0.98 in 1983 to a maximum of 21.70 mg/kg in 1999. Over this same period, average wet-weight fillet PCB concentration ranged from 3.15 in 1983 to 7.76 in 2000. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years for which data are available, 1983, 85, 86, 93, 99, and 2000.

Average adjusted PCB concentration ranged from 2.17 mg/kg in 1999 to 6.52 mg/kg in 1985. As with wet-weight concentrations, adjusted average concentrations also exceeded the 2.0 mg/kg MDCH general consumption advisory in all years for which data are available.

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.16 mg/kg in 1993 to a maximum of 2.35 mg/kg in 2000. Average wet-weight PCB concentration never exceeded the 2 mg/kg MDCH general consumption advisory level, but exceeded the 0.20 mg/kg MDCH one-meal-per-month advisory level for women and children in all years for which data are available (1985, 93, 99 and 2000).

Average adjusted concentrations ranged from 0.49 in 1993 to 3.76 in 1985. Average adjusted PCB concentrations exceeded the MDCH advisory limit of one-meal-per-month for women and children in all years in which data area available (1985, 1993, 1999 and 2000) and exceeded the general consumption advisory in 1985.

Other Species
Eleven pumpkinseed sunfish (*Lepomis gibosus*) were captured in 1999 and had wet-weight PCB concentration ranging from 0.18- to 0.60 mg/kg with average concentration of 0.35 mg/kg, exceeding the MDCH one-meal per month advisory for women and children.

4.3.5 Plainwell Impoundment

Carp
Since 1983, wet-weight PCB concentration in fillets ranged from a minimum of 0.50 in 1986 to a maximum of 21.54 mg/kg in 1999. Over this same period, average wet-weight PCB concentration ranged from 4.13 in 1986 to 10.33 in 1999. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years for which data are available from 1983 through 2001.

Average adjusted PCB concentration ranged from 3.01 mg/kg in 2001 to 9.15 mg/kg in 1985. As with wet-weight concentrations, adjusted average concentrations also exceeded the 2.0 mg/kg MDCH general consumption advisory level in every year sampled from 1983 through 2001.

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.09 mg/kg in 1997 to a maximum of 3.89 mg/kg in 1993. Average wet-weight PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory level in 1985 (3.25 mg/kg) and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Average adjusted PCB concentration ranged from 0.23 mg/kg in 1997 to 1.11 mg/kg in 1993. Adjusted average concentration exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

4.3.6 Otsego City Impoundment

Carp

Carp samples were collected from Otsego City Impoundment in 1993, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.30 in 2001 to a maximum of 8.03 mg/kg in 1993. Over this same period, average wet-weight PCB concentration ranged from 1.11 in 1999 to 3.44 in 1993. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in 1993 and 2001 and exceeded the 0.20 mg/kg MDCH one-meal-per-month for women and children in 1999.

Average adjusted PCB concentration ranged from 1.22 mg/kg in 1999 to 3.00 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level in 1993 and 2001 and exceeded the 0.2 MDCH one-meal-per-month advisory for women and children in 1999.

Smallmouth Bass

Wet-weight PCB concentration ranged from a minimum of 0.05 mg/kg in 2001 to a maximum of 3.66 mg/kg in 1993. Average wet-weight PCB concentration exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Average adjusted PCB concentration ranged from 0.98 mg/kg in 2001 to 1.08 mg/kg in 1993. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Other Species

Two channel catfish, 2 northern pike and 1 walleye (*Stizostedium vitrium*) were collected from Otsego City Impoundment. The channel catfish had wet-weight PCB concentrations of 4.74- and 5.40-mg/kg. The northern pike had wet-weight PCB concentrations of 0.06- and 0.84- mg/kg and the walleye had wet-weight PCB concentration of 0.89 mg/kg.

4.3.7 Otsego Impoundment

Carp

Carp samples were collected from Otsego Impoundment in 1993, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.29 in 1999 to a maximum of 49.54 mg/kg in 2001. Over this same period, average wet-weight PCB concentration ranged from 2.54 mg/kg in 1999 to 9.00 mg/kg in 2001. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years in which data are available, Average adjusted PCB concentration ranged from 2.37 mg/kg in 1999 to 3.66 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level (1993, 1999 and 2001).

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.31 mg/kg in 1999 to a maximum of 3.73 mg/kg in 1993. Average wet-weight PCB concentration ranged from 0.58 mg/kg in 1999 to 1.48 mg/kg in 1993 and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

Average adjusted PCB concentration ranged from 0.58 mg/kg in 1999 to 1.03 mg/kg in 1993. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

4.3.8 Trowbridge Impoundment

Carp
Carp samples were collected from Trowbridge Impoundment in 1993, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.64 in 1999 to a maximum of 16.01 mg/kg in 1999. Over this same period, average wet-weight PCB concentration ranged from 3.18 mg/kg in 1999 to 4.55 mg/kg in 1993. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all 3 years for which data are available,

Average adjusted PCB concentration ranged from 2.95 mg/kg in 1999 to 4.82 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level in 1993, 1999 and 2001.

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.43 mg/kg in 1999 to a maximum of 4.19 mg/kg in 1993. Average wet-weight PCB concentration ranged from 0.73 mg/kg in 1999 (BBL samples) to 1.95 mg/kg in 1993 and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

Average adjusted PCB concentration ranged from 1.0 mg/kg in 1999 to 1.59 mg/kg in 1993. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

Other Species
Four channel catfish and were captured from Trowbridge impoundment in 1999 with wet-weight PCB concentration ranging from 1.53- to 5.09-mg/kg. Two northern pike had concentrations 10.2- and 1.41-mg/kg and 1 walleye had 0.64 mg/kg PCB concentration.

4.3.9 City of Allegan Impoundment

Carp

Carp samples were collected from the City of Allegan Impoundment in 1999 and 2001 with wet-weight PCB concentrations ranging from 0.43-to 7.25-mg/kg both in 1999. Average wet-weight PCB concentration was 3.34- and 3.96-mg/kg in 1999 and 2001 respectively. These average concentrations exceed the 2 mg/kg MDCH general consumption advisory level.

Smallmouth Bass

Smallmouth Bass samples were also collected from the City of Allegan Impoundment in 1999 and 2001 with wet-weight PCB concentrations ranging from 0.14-to 0.93-mg/kg both in 1999. Average wet-weight PCB concentration was 0.52- and 0.56-mg/kg in 1999 and 2001 respectively. These average concentrations exceed the 0.20 mg/kg MDCH one-meal-per-month advisory level for women and children.

4.3.10 Lake Allegan

Carp

Carp samples were collected from Lake Allegan Impoundment in 1983 through 1987, 1990, 1992 through 1994, 1997 and 1999 through 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.09 mg/kg to 23.95 mg/kg, both in 1986. Average wet-weight PCB concentration ranged from 0.69 mg/kg in 2000 to 4.43 mg/kg in 1985. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years sampled from 1983, through 1992, and exceeded the 0.2 mg/kg one-meal-per-month limit for women and children from 1992 through 2001.

Average adjusted PCB concentration ranged from 0.73 mg/kg in 2001 to 3.72 mg/kg in 1985. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level in 1985 through 1990, and also in 1994. Average adjusted PCB concentration exceeded the 0.2 mg/kg one-meal-per-month limit for women and children from in all other years.

Smallmouth Bass

Wet-weight PCB concentration ranged from a minimum of 0.10 mg/kg in 2000 to a maximum of 5.80 mg/kg in 1993. Average wet-weight PCB concentration ranged from 0.35 mg/kg in 2000 to 3.29 mg/kg in 1993 and exceeded the 0.2 mg/kg MDCH one-meal-per-month level for women and children in all years sampled.

Average adjusted PCB concentration ranged from 0.51 mg/kg in 2000 (BBL samples) to 2.16 mg/kg in 1987. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Other Species

One black crappie (*Promoxis, nigromaculatus*) was captured in 1999 and 2000 with 1.16- and 0.4-mg/kg wet-weight PCB concentrations respectively. Eight bluegill sunfish (*Lepomis, Macrochirus*) were captured in 1999 with wet-weight PCB concentrations ranging from 0.2- to 0.7- and averaging 0.39-mg/kg. Twelve channel catfish were captured in 1999 with wet-weight PCB concentration ranging from 0.24- to 2.87- and averaging 1.09-mg/kg. Six channel catfish were captured in 2001 with wet-weight PCB concentration ranging from 0.61- to 3.77- and averaging 2.17-mg/kg. Two, 7 and 1 largemouth bass were caught in 1983, 1985 and 2000 respectively. Wet-weight PCB concentration ranged from 0.31 mg/kg in 2000 to 6.54 mg/kg in 1985. Three and 11 northern pike were sampled in 1987 and 1999 respectively, with wet-weight PCB concentration ranging from a minimum of 0.32- to a maximum of 4.60-mg/kg in 1999. Average concentration was 2.36- and 1.81-mg/kg in 1987 and 1999 respectively. Three pumpkinseed sunfish were sampled in 1999 with wet-weight PCB concentration ranging from 0.27- to 0.55-mg/kg. Eleven walleye were sampled in 1999 with wet-weight PCB concentration ranging from 0.18- to 1.53-mg/kg and 2 were sampled in 2000 with wet-weight PCB concentration 0.32- and 1.80-mg/kg. The overall average of these 13 walleye was 0.81 mg/kg, exceeding the MDCH one-meal-per-month advisory level for women and children.

4.3.11 Downstream of Lake Allegan Dam

Carp

Eleven carp samples were collected from the area just downstream of Lake Allegan dam in 1993. Wet-weight PCB concentration in fillets ranged from a minimum of 1.93 mg/kg to a maximum of 17.00 mg/kg. Average wet-weight PCB concentration was 7.6 mg/kg, exceeding the 2 mg/kg MDCH general consumption advisory level.

Smallmouth Bass

Eleven smallmouth bass were also collected in 1993 with wet-weight PCB concentration ranging from 1.05-to 2.42-mg/kg. Average wet-weight PCB concentration was 1.89 mg/kg exceeding the 0.2 mg/kg MDCH one-meal-per-month advisory level for women and children.

4.3.12 New Richmond

Carp

Carp samples were collected from the Kalamazoo River near New Richmond in 1993, 1997, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.20 mg/kg in 1999 to a maximum of 17.3 mg/kg, in 1997. Average wet-weight PCB concentration ranged from 2.55 mg/kg in 1999 to 4.95 mg/kg in 1993. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years sampled (1993, 1997, 1999 and 2001).

Average adjusted PCB concentration ranged from 2.39 mg/kg 1999 to 5.90 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level each year.

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.05 mg/kg in 1999 to a maximum of 4.3 mg/kg in 1997. Average wet-weight PCB concentration ranged from 0.54 mg/kg in 1993 to 1.07 mg/kg in 1997 and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled (1993, 1997, 1999 and 2001).

Average adjusted PCB concentration ranged from 0.60 mg/kg in 2001 to 1.25 mg/kg in 1997. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Other Species
Two channel catfish were sampled in 1999 with wet-weight PCB concentrations of 1.61- and 1.70-mg/kg. Four flathead catfish (*Pylodictis olivaris*) were sampled in 2001 and had PCB concentrations ranging from 0.60- to 3.32-mg/kg averaging 1.96 mg/kg. Two largemouth bass sampled in 1999 had PCB concentrations of 0.81- and 1.09-mg/kg , and 4 northern pike had PCB concentrations ranging from 0.33- to 0.46-mg/kg with an average of 0.39 mg/kg. Eleven Walleye were sampled in 1999 with PCB concentrations ranging from 0.03- to 0.92-mg/kg averaging 0.28 mg/kg.

4.3.13 Saugatuck

Carp
Carp samples were collected from Kalamazoo Lake and Douglas Bayou near Saugatuck in 1984 through 1987, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.06 mg/kg in 2001 to 25.70 mg/kg, in 1984. Average wet-weight PCB concentration ranged from 1.63 mg/kg in 2001 to 8.49 mg/kg in 1984. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit each year sampled from 1984 through 1999, and exceeded the 0.20 mg/kg MDCH one-meal-per-month for women and children in 2001.

Average adjusted PCB concentration ranged from 1.20 mg/kg in 2001 to 7.00 mg/kg in 1985. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level each year, with the exception of 1999 and 2001 when average adjusted concentrations exceeded the the 0.20 mg/kg MDCH one-meal-per-month for women and children in 2001.

Smallmouth Bass
Smallmouth bass samples were collected from Kalamazoo Lake and Douglas Bayou near Saugatuck in 1985, 1999 and 2001, although only one fish was collected in 1985. Wet-weight PCB concentration ranged from a minimum of 0.20 mg/kg in 1999 to a maximum of 1.71 mg/kg in 1985. Average wet-weight PCB concentration ranged from 0.43 mg/kg in 1999 to 1.71 mg/kg in 1985 and exceeded the 0.2 mg/kg MDCH one-meal-per-month level for women and children in all years sampled (1993, 1997, 1999 and 2001).

Average adjusted PCB concentration was not calculated in 1985 because only one fish was collected. Average adjusted PCB concentration was 0.38 mg/kg in 1999 and 0.61 mg/kg in 2001. Adjusted average concentration exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in both 1999 and 2001.

Other Species

Thirteen other species have been collected at Saugatuck since 1984

In 1987 a broad range of 13 other species were collected and analyzed for PCB concentration in edible portions. This included: 10 black crappie (ranging from 0.30- to 1.59- and averaging 0.70-mg/kg) 10 bluegill sunfish (ranging from 0.19- to 0.68- and averaging 0.43-mg/kg), 4 brown trout (ranging from 1.32- to 4.62- and averaging 3.73-mg/kg), 8 channel catfish (ranging from 3.45- to 12.41 and averaging 6.36-mg/kg), 3 flathead catfish (ranging from 1.71- to 22.20- averaging 13.71-mg/kg), 10 largemouth bass (ranging from 0.52- to 2.02- averaging 1.10-mg/kg), 10 northern pike (ranging from 0.36- to 3.36- and averaging 1.33-mg/kg), 10 rainbow trout (*Oncorhyncus, mykiss*) (ranging from 0.24- to 0.73- and averaging 0.44-mg/kg), 10 rock bass (ranging from 0.17- to 0.52- and averaging 0.37-mg/kg), 10 walleye (ranging from 0.33- to 1.48- and averaging 0.58-mg/kg), 10 white sucker (ranging from 0.44- to 2.82- and averaging 1.08-mg/kg) and 10 yellow perch (ranging from 0.06- to 1.20- and averaging 0.43-mg/kg).

For those species that were sampled in years other than 1987, the average wet-weight PCB concentrations are discussed below. Average PCB concentration in channel catfish ranged from 2.53 mg/kg in 1999 to 6.36 mg/kg in 1987. Average PCB concentration in largemouth bass ranged from 0.56 mg/kg in 1985 to 1.33 mg/kg in 1985. Largemouth bass have not been sampled since 1987. Northern pike averaged 1.33 mg/kg in 1987 and 0.26 mg/kg (n=4) in 1999. PCB concentration in walleye averaged 0.58 mg/kg in 1987 and 0.18 mg/kg in 1999.

4.3.14 Saugatuck Near River Mouth

Carp

Five carp were captured in 1993 near the Kalamazoo River Mouth at Lake Michigan and a single composite sample was analyzed with PCB concentration 1.09 mg/kg.

4.3.15 Portage Creek-Monarch Mill Pond

Carp

Carp were sampled from Monarch Mill Pond on Portage Creek in 2001 as part of the MDEQ long term monitoring program. PCB concentration among 11 fish ranged from 0.05- to 0.47- and averaged 0.18-mg/kg below the 0.2 mg/kg MDCH one-meal-per-month advisory level for women and children, but above the 0.11 MDEQ risk-based cleanup goal.

4.3.16 Portage Creek-Bryant Mill Pond

Carp

Carp samples were collected from Bryant Mill Pond, on Portage Creek in 1985, 1986, 1987, 1993, 2000 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.05 mg/kg in 2000 to a maximum of 27.37 mg/kg, in 1986. Average wet-weight PCB concentration ranged from 0.36 mg/kg in 2000 to 3.97 mg/kg in 1986. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in (1985, 1986, 1987 and 1993) and exceeded the 0.2 mg/kg MDCH one-meal-per-month advisory level for women and children in 1987, 2000 and 2001. PCB contaminated paper residuals and sediment were removed from Bryant Mill Pond in 1998 and 1999, which may in part explain reduced concentrations found in 2000 and 2001.

Prior to the removal, average adjusted PCB concentration ranged from 2.01 mg/kg in 1993 to 4.65 mg/kg in 1985, exceeding the 2 mg/kg general population consumption advisory level. After the removal action, site-wide average adjusted concentrations were 0.30- and 0.44-mg/kg in 2000 and 2001 respectively, below the 2.0 mg/kg consumption advisory, but exceeding the 0.2 mg/kg MDCH one-meal-per-month for women and children after the removal action. The removal action focused on removal of PCB contaminated sediment and stream-bank restoration. These results are thought to provide direct evidence of the positive effect of contaminated sediment removal (Day, 2002).

that removal of PCB contaminated sediments contribute to reduced PCB concentration in fish tissue.

Other Species

In 2000, one 22-cm long brown trout (*Salmo, trutta*) was captured from Bryant Mill Pond after the removal action was completed in 1999. This wet-weight PCB concentration was 0.05 mg/kg. below the 0.11 mg/kg MDEQ risk based central tendency angler cleanup goal.

4.4 Spatial Trends in Fish Exposure to PCB

4.4.1 Spatial Trends

Naïve interpretation of spatial trends in wet-weight PCB concentration in carp fillets differ from those based on lipid- and length-adjusted concentration. For example, wet-weight concentration was in general higher in carp fillets from Plainwell than those from Lake Allegan (Table 1; Figure 9), although, after adjusting for covariation with length and lipid based on site-wide averages, concentrations at Plainwell Impoundment were similar to those at Lake Allegan (Table 1; figure 9). This indicates that bioaccumulation of PCB at Lake Allegan and Plainwell Impoundment may be similar and that differences in wet-weight PCB concentrations are due in part to differences in the lipid and length distributions of fish from these ABSA.

Carp

In 2001, average adjusted PCB concentration increased with distance downstream from 0.41 mg/kg at Battle Creek to 3.31 mg/kg at Trowbridge Impoundment (Figure 9). Average adjusted PCB concentration at Plainwell Impoundment (1.73 mg/kg) was similar to that at Lake Allegan (1.59 mg/kg). Average adjusted fillet PCB concentration at New Richmond (2.12 mg/kg) was similar to that at Otsego City (2.05 mg/kg) and Otsego (2.54 mg/kg) Impoundments. Average adjusted fillet PCB concentration at Saugatuck (0.83 mg/kg) was similar to that at Morrow Pond (0.74 mg/kg).

Smallmouth Bass

The relative spatial distribution of average adjusted PCB concentration in smallmouth bass in 2001 was similar to that for carp. The lowest average adjusted PCB concentration (0.03 mg/kg) occurred at Battle Creek and the highest adjusted average PCB concentration (1.04 mg/kg) occurred at Trowbridge Impoundment. Average adjusted concentrations in general increased with distance downstream from Battle Creek followed by a decline with distance downstream from Trowbridge Impoundment. Adjusted average PCB concentration was lower at Battle Creek and Morrow Pond than at any ABSA downstream of Morrow Dam.

4.5 Temporal Trends

Mean adjusted PCB concentration for carp and smallmouth bass was modeled assuming that the mean followed a mixed order model with lognormal error. Parameters were estimated by the method of maximum likelihood (Casella and Berger 1990) and are summarized in Table (4).

Three parameters are reported in Table (4) including an estimate of the percentage reduction per year in concentration $Diff = (C_{final} - C_{initial})/(\overline{C} \times \Delta t) \times 100\%$ with 95% confidence limits and the significance level for a one sided test of the null hypothesis of no decrease in concentration. This test is analogous to testing for a significant negative slope in the first order decay model. However, a reduction in PCB concentration over the monitoring period does not imply that future reductions will continue at the same decay rates.

When there is significant decay in concentration, *2* determines the shape of the decay function. The maximum likelihood estimate of *2* is included in Table (4) with 95% confidence limits. The statistical significance probability for the null hypothesis of exponential decay (i.e., H_0:*2*=0) is also reported. Deviation from exponential decay rates can also be assessed graphically by looking at the plotted models in Figures (11) through (33). The plots are in natural log scale, so when decay rates are exponential, the plotted model is linear. When the decay rate is decreasing/increasing the plotted models are concave up/down respectively.

Finally, the standard deviation of the log-normal distribution F is also reported with 95% confidence limits. Tests of significance and confidence limits for model parameters were estimated by bootstrap resampling.

Trend models were estimated for each ABSA using all available data, and data collected since 1990. For each combination of species, ABSA and data subset, the data were adjusted to represent; 1) fish with ABSA-specific-average length and lipid fraction, and 2) fish with site-wide-average length and lipid fraction. The resulting models are plotted in Figures (11) through (33). Each figure where data are available prior to 1990 contains 4 panels. Panels (A) and (B) contain models for the ABSA-specific and Site-wide adjustments respectively and are based on all available data. Panels (C) and (D) contain models for the ABSA-specific and site-wide adjustments respectively but are based on data collected from 1990 forward.

Each plot contains 4 horizontal lines; at 2.0 mg/kg representing the MDCH general consumption; 0.2 mg/kg representing MDCH one-meal-per month advisory; 0.11 mg/kg representing the MDEQ risk based cleanup goal protective of central tendency anglers; and 0.05 mg/kg representing the MDCH one meal per week criteria for women and children. The estimated mixed order model is plotted with a black line and upper and lower 95% confidence limits are plotted with blue lines. Confidence limits were estimated by bootstrap resampling. The sample mean adjusted PCB concentration is also plotted for each year with 95% bootstrap confidence limits.

In the following, trend analysis results are discussed on an ABSA basis, so trends in ABSA-specific adjusted concentrations are discussed. These models are plotted in panels (A) and (C) in the corresponding figures. Models plotted in Panels (B) and (D) are appropriate for among ABSA comparisons, although they are not discussed in detail below.

4.5.1 Battle Creek

Carp

ABSA-specific adjusted PCB concentration in carp 1986 through 2001 (Model I) and 1990 through 2001 (Model II) did not decline significantly (p>0.70). Plotted models in Figure (11) indicate that adjusted fillet PCB concentrations may be at equilibrium. It is anticipated that in the near future, PCB concentrations in carp fillets will remain similar to current levels, provided that lipid fraction and size distributions of fish remain similar.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets have declined at an average annualized rate of 9.4- to 10.4-percent per year since 1994 ($p<0.002$). Adjusted PCB concentrations in 1994 and 1997 were similar and higher than in fish sampled in 1999 through 2001 (Figure 12).

The observed decay rate was similar to exponential ($p > 0.31$) for both ABSA-specific and site-wide adjusted data.

It should be noted that the temporal record for smallmouth bass at Battle Creek is short (1994-2001) so forward projections should be viewed with caution.

4.5.2 Morrow Pond

Carp
ABSA-specific adjusted PCB concentration in carp declined at an average annualized rate of 10% (95% confidence limits: 5% to 20%) from 1986 through 2001 (Model I). Decay rates from 1993 through 2001 (Model II) were similar (10%) although 95% confidence intervals were wider (3% to 20%) due primarily to the restricted number of years analyzed. Plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential ($p=0.15$; Figure 13 panel A) indicating that decay rates may be decreasing with time. Carp fillet concentrations are currently below the 2 mg/kg MDCH general consumption advisory level and are expected to approach the 0.2 MDCH one-meal-per-month advisory level by 2010 (95% CL: 2005 to >2020: Figure 13, Panel A).

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at an average annualized rate of 16% (95% CL: 9.5% to 24%) from 1985 through 2001 (Model I). Decay rates from 1993 through 2001 (Model II) were slower (11.2%; 95% CL: 5% to 20%) Based on the full data set, plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential ($p=0.26$; Figure 14 panel A) indicating that decay rates may be decreasing with time. Smallmouth bass fillet concentrations are currently below the 0.2 mg/kg MDCH one-meal-per-month advisory level and near to the 0.11 mg/kg MDEQ risk based level necessary to protect central tendency anglers. Future projections indicate that concentration will be below this risk based level by 2007 with 95% level of confidence. Based on the 1993 through 2001 data, one would expect average concentrations to be below the risk based level before 2005.

4.5.3 Downstream of Morrow Dam

Fish samples were collected from the area below Morrow Dam in 1993 and 2000 providing just 2 points in time from which to infer temporal trends. These data are probably not adequate to make reliable forecasts of PCB concentration, nor are tests for exponential decay reliable. Nonetheless, the MO model was estimated for these data and the results are plotted on Figures (15) and (16). Adjusted average PCB concentration was lower in 2000 than in 1993 for both carp and smallmouth bass samples ($p<0.015$). Annualized decay rates were slower than at Morrow Pond, 7.9% (95% CL: 2.3% to 15.1%) for carp and 7.4% (1.0% to 13.5%) for smallmouth bass.

4.5.4 Mosel Avenue

Carp

ABSA-specific adjusted PCB concentration in carp declined at an average annualized rate of 3% (95% confidence limits: 1% to 5%) from 1983 through 2001 (Model I). Decay rates from 1993 through 2000 (Model II) were similar (4%; 95% CL: 0.3% to 9%). The best-fit model was concave-up, but the decay rate was not statistically different from exponential ($p=0.33$; Figure 17 panel A). Adjusted carp fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 2000 and may remain there beyond 2020. It is expected that PCB concentrations will remain above 0.2 mg/kg (MDCH one-meal-per month advisory) through 2020 with 95% level of confidence.

Smallmouth Bass

ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at an average annualized rate of 10% (95% CL: 3% to 17%) from 1985 through 2000 (Model I; Figure 18-A) but increased from 1993 through 2000 (Model II; Figure 18-B) at a rate of 4% (95% CL: 8% to 0%) Based on the full data set, plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential ($p=0.26$; Figure 18-A) indicating that decay rates may be decreasing with time. Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month for women and children level. Future projections based on all data indicate that concentration will be above this one-meal-per-month level through 2015 with 95% level of confidence. The 1993 through 2000 data, indicate that average concentrations may remain above the 0.2 mg/kg level indefinitely and could approach the general consumption advisory level.

4.5.5 Plainwell Impoundment

Carp

ABSA-specific adjusted PCB concentration in carp declined at an average annualized rate of 5% (95% confidence limits: 2% to 9%) from 1983 through 2001 (Model I; Figure 19-A). Decay rates from 1993 through 2001 (Model II; Figure 19-C) were similar (5%; 95% CL: -0.1% to 9%). The best-fit model was concave-up but the decay rate was similar to exponential ($p=0.24$; Figure 19-A). Adjusted carp fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 2001 and may remain there beyond 2020. It is expected that PCB concentrations will remain above 0.2 mg/kg (MDCH one-meal-per month advisory) through 2020 with 95% level of confidence.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined with an average annualized rate of 9% (95% CL: 0.8% to 17%) from 1993 through 2001. Plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential ($p=0.10$; Figure 20-A) indicating that decay rates may be decreasing with time. Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption advisory level but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children. Future projections based on the best fit model indicate that PCB concentration will be above this one-meal-per-month level through 2010 with 95% level of confidence and may remain there beyond 2020.

4.5.6 Otsego City Impoundment

Carp
ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 5% ($p=0.06$; 95% confidence limits: -1.2% to 14.7%) from 1993 through 2001 (Figure 21-A). The best-fit model was concave-up and the decay rate was slower than would be expected under the first order decay assumption($p=0.048$; Figure 21-A) indicating that decay rates may be decreasing with time. Adjusted carp-fillet PCB concentrations were below the 2 mg/kg MDCH general consumption advisory level in 1999 ($p < 0.05$) and above the general consumption advisory level in 2001. Lower 95% confidence limit for adjusted concentrations is projected to remain above the 0.2 MDCH one meal-per-month advisory level through at least 2020. Upper 95% confidence limits indicate that concentrations could remain above the 2 mg/kg general consumption advisory limit beyond 2020. The best estimate for PCB concentration in 2020 is approximately 1 mg/kg (MDCH 6 meal per year advisory).

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets remained unchanged from 1993 through 2001 ($p=0.40$; Figure 22-A). Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children. Under current site conditions, future concentrations can be anticipated to remain similar provided that fish length and lipid-fraction distributions remain similar.

4.5.7 Otsego Impoundment

Carp
ABSA-specific adjusted PCB concentration in carp fillets did not decline ($p=0.47$; 95% confidence limits: -8% to 8%) from 1993 through 2001 (Figure 23-A). Adjusted carp-fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 1993, 1999 and 2001 ($p < 0.05$). Given the lack of evidence of any temporal trend in PCB concentration it is expected that under current site conditions, future concentrations will be similar to those observed over this 3 year period.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at a 7% average annualized rate from 1993 through 2001 (95% confidence limits 3.2 to 13.3; Figure 24-A). Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children and under current site conditions are projected to decline to near this level by 2020.

4.5.8 Trowbridge Impoundment

Carp
ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 8% (95% Confidence limits: 2% to 14%) from 1993 through 2001 (Figure 25-A). Decay rates were different from exponential ($p=0.13$) indicating that future decay rates are expected to decline with time. Adjusted carp-fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 1993, 1999 and 2001 ($p < 0.05$). and may continue to exceed this level through 2020. PCB concentrations are projected to remain above the 0.2mg/kg MDCH one-meal per month advisory level through 2020 with 95% confidence.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at a 7% average annualized rate (95% Confidence limits: 4% to 11%) from 1993 through 2001 ($p<0.010$; Figure 26-A). Estimated decay rates were similar to exponential. Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption advisory level, but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children. Under current site conditions concentrations are expected to remain above this level through 2012 ($p=0.025$) and are likely to exceed this level beyond 2020.

4.5.9 Lake Allegan

Carp
ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 9% (95% CL: 7% to 10%) from 1993 through 2001 (Figure 27-A). The decay rate was similar to exponential ($p=0.55$). The estimated annualized decay rate from 1993 through 2001 was similar to that based on all data (14%; 95% CL: 7% to 24%) but the decay rates was slower than exponential ($p=0.05$) indicating that decay rates may be decreasing with time.

Adjusted carp-fillet PCB concentrations were below the 2 mg/kg MDCH general consumption advisory level in 2001 ($p < 0.05$). Based on all data, adjusted PCB concentration is expected to be above the MDCH 0.2 mg/kg advisory level through approximately 2007 with 95% confidence and is expected to remain above this level through 2010.

Future projections of PCB concentrations at Lake Allegan are heavily influenced by PCB concentration in carp fillets collected in the 1980s. Average adjusted PCB concentration projections in 2020 were below the 0.11 mg/kg MDEQ risk based level when all data were considered. However, projected concentrations were greater than the 0.2 mg/kg advisory level when the model was restricted to data from 1993 through 2001.

Smallmouth Bass

ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at a 15% (95% CL: 11% to 21%) average annualized rate from 1993 through 2001 ($p<0.001$; Figure 28-A). Estimated decay rates were similar to exponential ($p=0.71$). Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children and under current site conditions are expected to remain above this level through 2007 ($p=0.025$) and are likely to exceed this level beyond 2015.

From 1993 through 2001, adjusted PCB concentrations decayed at an 11% average annualized decay rate (95% CL: -.05 to 25%). Decay was slower than exponential ($p=0.01$) indicating that decay rates may be decreasing with time. Based on this more recent data, PCB concentrations are projected to be above the 0.2- and 0.11-mg/kg advisory levels through at least 2007 and 2012 respectively with 95% confidence. Concentrations may remain above the 0.2 mg/kg advisory level beyond 2020, based on 95% upper confidence limits.

4.5.10 New Richmond

Carp

ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 11% (95% CL: 0.7% to 25%) from 1993 through 2001 (Figure 29-A). The decay rate was slower than expected for exponential decay ($p=0.07$) indicating that decay rates may be decreasing with time.

Adjusted carp-fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 2001 ($p < 0.05$). Adjusted PCB concentration is expected to be above the MDCH 0.2 mg/kg advisory level through approximately 2015 with 95% confidence and may remain above this level through 2010. Upper 95% confidence limits indicate that PCB concentration may exceed 2 mg/kg beyond 2020.

Smallmouth Bass

ABSA-specific adjusted PCB concentration in smallmouth bass fillets did not decline from 1993 through 2001 ($p=0.74$; Figure 30-A) and may be increasing. Concentrations are expected to remain below 2 mg/kg and above 0.2 mg/kg through 2020.

4.5.11 Saugatuck

Carp

ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 7.5% (95% CL: 4.0% to 10.0%) from 1983 through 2001 (Figure 31-A). The decay rate was similar to exponential decay (p=0.44).

Adjusted fillet PCB concentrations were above the 0.2 mg/kg MDCH general consumption advisory level in 2001 ($p < 0.05$). Adjusted PCB concentration is expected to remain above the MDCH 0.2 mg/kg advisory level through approximately 2010 with 95% confidence and may remain above this level beyond 2020. Upper 95% confidence limits indicate that PCB concentration may exceed 2 mg/kg through 2015.

Smallmouth Bass

Smallmouth bass were collected in 1997 and 2001 only. The MO model was fit to the data, but estimated temporal trends may not be reliable (Figure 32).

4.6 Comparison With Other Sites

Whole body carp from Lake Allegan had significantly higher PCB concentrations than those from 3 of the 4 inland sites, (Raisin, Grand and Muskegon Rivers) and 3 of the 7 great lakes sites (Lake St. Clair, Munuscong Bay, Thunder Bay; $p<0.05$). Whole-body carp from the St. Joe River had lower PCB concentrations than those at Lake Allegan, although differences were not statistically significant at the 0.05 level (Figure 33). PCB concentrations in whole-body carp from Lake Allegan were similar to those at Lake Erie, Grand Traverse Bay, the Detroit River, Saginaw Bay and the St. Joe River.

After adjusting for variation in length and lipid-content, geometric mean PCB concentration in whole-body carp from Lake Allegan (4.75 mg/kg) was exceeded only by that from Lake Erie (6.1 mg/kg). PCB concentrations in whole-body carp at Lake Allegan were similar to those from the remaining great lakes sites where lipid- and length-adjusted geometric mean PCB concentrations ranged from 0.5- to 6.1 mg/kg.

With the exception of Lake Allegan and the St. Joe River, PCB concentrations in whole-body carp from inland-river sites were generally lower than those from great-lakes and connecting waters sites. One notable exception was at Munuscong Bay along the St. Maries River which connects Lakes Superior and Huron. Munuscong Bay had the second lowest geometric mean concentrations (GM=0.25 mg/kg) among all sites. The only site with lower adjusted PCB concentrations was the Muskegon River (GM=0.02 mg/kg).

Section 5
Fish Consumption Advisories

5.1 Consumption Advisory Criteria

The MDCH has two distinct sets of criteria for what is termed the general population as opposed to women of child bearing age and children. These criteria are spelled out in sections 5.1.1 and 5.1.2. MDCH compares wet-weight total PCB concentration to the criteria without regard to lipid distributions. Attempts are made to control for fish size and age by limiting the size distribution of fish retained for analysis. Wet-weight PCB concentration in carp and smallmouth bass fillets collected from 1998 through 2001 were compared with these criteria and summarized in Table (6). Because the MDCH and MDEQ consider other factors when setting fish advisories on waters of the state, these results should not be considered as an endorsement to consume fish from the Kalamazoo River, nor are they a recommendation to the MDCH/MDEQ for setting consumption advisories.

5.1.1 General Population

For the general population, PCB concentrations are compared to the 2.0 mg/kg level. When 50% or more of samples have concentration greater than 2.0 mg/kg a no consumption advisory would be put in place. When 11% to 49% of samples are greater than 2.0 mg/kg a one meal per week limit is recommended. When less than 11% of samples are below the MDCH criteria, unlimited consumption is permitted.

5.1.2 Women of Child Bearing Age and Children

Fish consumption advisories for women of child bearing age and children less than 15 years of age are based on average concentration rather than sample percentages. A no-consumption advisory is recommended when average concentration is greater than 1.9 mg/kg. When average concentration is between 1.0- and 1.9-mg/kg no more than 6 meals per year are recommended. When average concentration is between 0.2- and 1.0-mg/kg no more than one-meal-per-month is recommended. When average concentration is between 0.05- and 0.2-mg/kg no more than one meal per week is recommended, and when average concentration is below 0.05 mg/kg, unlimited consumption is permitted.

5.2 Comparison of Fillet data to Advisory Criteria

Wet-weight Total PCB concentrations for carp and smallmouth bass collected from 1998 through 2001 were compared to MDCH fish consumption criteria as described in sections 5.1.1 and 5.1.2. The results of these comparisons are summarized in Table (6).

5.2.1 Smallmouth Bass

If advisories were based solely on these criteria applied to fillets collected in 1999, 2000 and 20001, unlimited consumption of smallmouth bass could currently be permitted at all sites for the general population, but only at Battle Creek for women and children. No more than one meal per week would be permitted at Morrow Pond and no more than one-meal-per-month could be permitted at the remaining sites excluding Trowbridge Impoundment where women and children would be limited to six meals per year.

5.2.2 Carp

For carp, unlimited consumption would only be permitted for the general population at Battle Creek, Morrow Pond, Monarch Mill Pond, each of which are upstream of the superfund site, and former Bryant Mill Pond where the removal action took place in 1998-99. No consumption would be advised from Morrow Dam to Plainwell Dam, Otsego Impoundment, Trowbridge Impoundment and Allegan City Impoundment. No more than one meal per week would be advised at the remaining areas, Otsego City Impoundment, Lake Allegan and Lake Allegan Dam to Lake Michigan.

For women and children, no consumption would be advised at all areas from Morrow Dam downstream to Allegan City Dam and from Lake Allegan Dam downstream to Lake Michigan. No more than six meals per year would be advised from Lake Allegan. No more than one-meal-per-month would be advised for Battle Creek, Morrow Pond and Bryant Mill Pond, and no more than one meal per week would be advised from Monarch Mill Pond.

Section 6
Findings and Conclusions

6.1 General Findings

The distribution of fish length and lipid fraction varied both spatially and temporally and explained a significant proportion of variation in fillet PCB concentration in both carp and smallmouth bass. Failure to adjust wet-weight PCB concentration for covariation with length and lipid may result in erroneous interpretations of PCB trends. We adjusted wet-weight PCB concentration in two ways; (1) based on within ABSA average of length and lipid, and (2) based on the overall site-wide average of length and lipid.

Within-ABSA adjusted data are representative of long-term exposures that fish consumers could expect from fish from a particular ABSA. Differences among these ABSA-specific adjusted concentrations could be due to differences in fish exposures to PCB, differences in lipid and length distributions or both. Fish exposures to PCBs can in turn be influenced by PCB concentration in sediment, water and prey, as well as other factors such as longevity, behavior, and species specific physiology. Alternatively, PCB concentration adjusted to length and lipid distributions representing site-wide averages can be interpreted as an indicator of site conditions after controlling variations in lipid and length. Among ABSA differences in site-wide adjusted concentrations indicate differences in site conditions controlling fish bioaccumulation of PCB.

6.1.1 Study Limitations

Full understanding and correct interpretation of any scientific data should include a discussion of potential limitations of the study design and or implementation. In this study, fish fillet data were generated by multiple scientific teams with varying objectives and field sampling and handling methods. Temporal variation may be confounded with field technicians, laboratories and analytical methods,although we found no evidence of systematic bias. Additionally, forward projections of tissue PCB concentrations are based on the assumption that fitted models are appropriate. For any model based analysis statistical inferences and confidence limits for temporal forecasts are conditional on the class of allowable models—in this case the mixed order and exponential decay models. Verification of findings of this study will require continued monitoring of PCB concentrations in carp and smallmouth bass fillets maintaining consistent field methods and laboratory standard operating procedures.

6.2 Fillet PCB as an Indicator of Site Conditions

Adjusted PCB concentration based on site-wide adjustments is a general indicator of fish bioaccumulation of PCB. Since the early to mid 1980s, fish bioaccumulation of PCB contamination at most ABSA has declined. The rate of these declines varies with species, location and time. For example at Mosel Avenue from 1990 through 2001, adjusted PCB concentration in carp fillets dropped at an annualized rate of 4% while adjusted concentrations in smallmouth bass fillets remained essentially unchanged or may have increased. Conversely, at Battle Creek, adjusted PCB concentrations in carp fillets were unchanged from 1987 through 2001, while concentrations in smallmouth Bass were declining at a 9- to 10% annualized rate. PCB concentrations in smallmouth bass at Mosel Avenue have apparently not changed since 1993. At Plainwell Impoundment, PCB concentration declines in carp fillets have slowed from a 5.8% average annualized rate from 1983 through 2001, to a 4.6% rate in the 1990s through 2001. While these changes in decay rate are fairly small, they may translate into fairly large differences in the time required to attain remedial objectives. Assuming that PCB concentration will decay exponentially in the future may result in overly optimistic projections of the performance of natural attenuation as a remedial alternative.

In general, after controlling for variations in lipid and length distributions, fish within the superfund site are exposed to and have accumulated higher PCB concentrations than those upstream of the site (Battle Creek, Morrow Pond; Figure 9). For carp, exposure to PCB increases with distance downstream from Morrow Pond with a maximum at Trowbridge Impoundment. Carp exposures to PCB at Lake Allegan, New Richmond and Saugatuck are lower than at Trowbridge, but similar to Plainwell and Otsego City Impoundments. It is interesting to note that wet-weight concentrations at Plainwell are much higher than at Lake Allegan, while after controlling for length and lipid variation fillet concentrations are similar.

6.3 Exposure of Fish Consumers to PCB

Fillet PCB concentration adjusted to ABSA-specific average length and lipid levels are an indicator of the expected long-term exposure that fish consumers could expect from eating fish from a particular ABSA. These adjusted data incorporate the exposures that fish are receiving as well as accounting for differences in the historic distribution of length and lipid among ABSA. For example, since the 1980s carp collected form Lake Allegan have historically been smaller and have had lower lipid levels than at Plainwell Impoundment. So, although carp are exposed to similar concentrations of environmental PCB at both ABSA, fish consumers could expect higher long-term exposures of PCB from Plainwell Impoundment than from Lake Allegan because fish consumers can expect to catch larger carp with higher lipid levels at Plainwell.

In 2001, fish consumers could expect an average exposure of 2- to 4- mg/kg wet-weight PCB from carp fillets at Plainwell, Otsego City, Otsego and Trowbridge and Allegan City Impoundments and in the Kalamazoo river near New Richmond (Table 1; Figure 9). These concentrations are at levels that would trigger MDCH no-consumption advisories for all potential consumers

The expected average exposures at Lake Allegan and Saugatuck were somewhat lower, (0.7- and 1.2-mg/kg respectively) but at levels that would trigger some form of consumption advisory. All concentrations were greater than the MDCH risk based cleanup goal protective of central tendency sport anglers.

PCB concentrations in fish tissues are a function of concentration in water, sediment and prey, lipid content and exposure duration, indexed by age or length. Although current PCB concentrations in Lake Allegan carp are lower than at surrounding ABSA (New Richmond and Allegan city Dam) this is primarily due to differences in lipid and length distributions. If changes in environmental conditions or fisheries management practices were to induce an increase in the lipid fraction in carp at Lake Allegan, PCB concentrations would be expected to increase to levels similar to those at other ABSA within the superfund site.

Estimated long-term exposure to PCB for consumers of smallmouth bass in 2001 was lower than that for consumers of carp. Long-term exposures at ABSA within the superfund site in 2001 are estimated to range from 0.5- to 1-mg/kg, while those at Battle Creek and Morrow Pond are estimated to be approximately 0.03- and 0.09-mg/kg respectively (Table 1 and Figure 9).

With the exception of Lake Allegan, PCB concentration in carp fillets from ABSA within the superfund site are expected to range from approximately 0.6- to 3.0-mg/kg in 2020 (Figure 34). These predictions are precise to approximately one order of magnitude. The difference between no-consumption and limited-consumption criteria is approximately one order of magnitude, so it is difficult to predict whether consumption advisory limits for carp would be lifted by 2020. Average PCB concentrations in carp fillets at Lake Allegan are expected to range from less than 0.01 to approximately 0.3 mg/kg.

Under existing conditions, PCB concentrations in smallmouth bass fillets from ABSA within the superfund site are expected to range from approximately 0.1- to 1.0 mg/kg in 2020. As with PCB concentrations in carp fillets, PCB concentrations in smallmouth bass fillets at Lake Allegan are expected to be lower than at other ABSA, ranging from 0.006- to 0.2-mg/kg.

These predictions are based on the assumption that the MO is appropriate for evaluating these data. At most ABSAs, the MO and first order decay models fit the data equally well. At some ABSAs we reject the hypothesis of exponential decay. For the most part, the decay rate of the best MO declined with time, but differences from exponential decay were not statistically significant. This suggests that PCB decay rates in carp and smallmouth bass fillets cannot be expected to continue at rates observed in the 1980s and early 1990s. In general, existing data are not adequate to precisely determine the rate at which PCB concentrations will decay in the near future. The rapid decay rates observed from the early 1980s to 1990 tend to dominate estimates of future decay rates. More recent data suggest that decay rates are beginning to slow, although the currently available temporal record is not adequate to precisely estimate the degree to which decay rates may be changing.

Based on the existing data it is likely that, at most ABSA, some form of consumption advisory will continue through 2020 for carp. In particular, concentrations are most likely to remain elevated at Plainwell, Otsego City, Otsego, Trowbridge and Allegan City Impoundments.

6.4 Comparison of Wet-weight PCB Concentrations to Advisory Criteria

Wet-weight PCB concentrations in carp from throughout the superfund site are at levels that would trigger some form of consumption advisory. At the three former impoundments (Plainwell, Otsego and Trowbridge) wet-weight PCB concentrations are at levels that would trigger a no-consumption advisory.

Upstream of the superfund site, (Battle Creek, Morrow Pond and Monarch Mill Pond) PCB concentrations are at levels where the general population could be permitted unlimited consumption. At these same sites, wet-weight concentrations are such that women and children would be restricted to one-meal-per-month with the exception of Monarch Mill Pond where women and children could eat one meal per week.

At all ABSA including those up stream of the superfund site, wet-weight PCB concentrations in carp fillets are above the risk-based 0.11 mg/kg MDEQ cleanup goal protective of central tendency sport anglers. Wet-weight PCB concentration in smallmouth bass fillets in 1999, 2000 and 2001 are sufficiently low that general-population consumption advisories would not be triggered at any ABSA.

For women and children, unlimited consumption of smallmouth bass fillets could be permitted at Battle Creek, but some form of advisory would be triggered at all other ABSA. At all sites except Battle Creek, Average Wet-weight PCB concentration in smallmouth bass were higher than the risk-based 0.11 mg/kg MDEQ cleanup goal designed to be protective of central tendency sport anglers.

6.5 Interim Removal Action at Former Bryant Mill Pond

There has been considerable debate about the potential for environmental dredging to produce short- or even long-term reductions in fish tissue contaminant concentrations (General Electric 2000). However, the majority of sediment removal actions cited by General Electric involved removal of localized hot-spots which may have only minimally impacted the overall average concentrations to which biota are exposed. However, a remedial action conducted in Sweden, (Gullbring et al. 1998) included dredging of expansive areas of Lake Jarnsjon resulting in post remedial average sediment concentrations below 1.0 mg/kg. At this site, follow-up studies of fish tissue concentrations (Bremle, 1998) indicated that PCB concentrations had declined in the first year after the remediation, although reductions could not be separated from that expected through natural attenuation.

At Former Bryant Mill Pond on Portage Creek, a similar approach was taken in that nearly all PCB containing sediments were removed from the currently and formerly impounded areas area rather than attempting to isolate and remove individual hotspots. Carp were sampled both before and after the removal action, and post removal concentrations are substantially lower than would have been expected under natural attenuation (Figure 35). Under a no action alternative, concentrations at Bryant Mill Pond are predicted to have been around 1.0 mg/kg in 2020. In 2000 and 2001, after the removal action, Carp fillet concentrations averaged 0.3 mg/kg and 0.4 mg/kg respectively. This suggests that the removal action may have accelerated recovery by over 20 years relative to natural attenuation. These data support the hypothesis that environmental dredging can be successful when contaminant deposits are properly delineated and a conservative approach is used to identify and remove potentially contaminated sediments.

Section 7
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Tables

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

				Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)							
							Site-wide		ABSA-specific					
Species	Source[3]	Year	N	Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm^3
BATTLE CREEK														
CARP	MICH	1987	9	0.03	0.24	0.12	0.10		0.09		52.0	1736	2.47	1.18
	MICH	1991	5	0.03	0.73	0.27	0.90	0.90	0.67	0.63	55.8	2260	0.93	1.30
	BBL	1993	11	0.06	0.17	0.08	0.10	0.10	0.09	0.09	56.8	2872	1.22	1.56
	BBL	1997	11	0.04	0.27	0.09	0.23	0.23	0.19	0.19	55.6	2491	0.75	1.44
	LTM	1999	11	0.04	0.29	0.09	0.07	0.07	0.06	0.06	56.0	2624	2.62	1.46
	LTM	2000	11	0.06	0.38	0.20	0.13	0.13	0.11	0.10	57.5	2966	3.07	1.55
	LTM	2001	11	0.06	1.17	0.40	0.41	0.41	0.41	0.42	59.1	3082	3.28	1.49
LARGEMOUTH BASS	MICH	1987	1	0.02	0.02	0.02					36.5	700	0.60	1.44
SMALLMOUTH BASS	MICH	1987	1	0.04	0.04	0.04					38.0	650	0.50	1.18
	MICH	1991	4	0.03	0.18	0.09					29.5	310	0.83	1.21
	BBL	1993	11	0.05	0.31	0.13	0.06	0.06	0.05	0.05	36.5	1124	1.41	2.29
	BBL	1997	11	0.03	0.08	0.05	0.05	0.05	0.05	0.05	38.3	891	0.50	1.57
	LTM	1999	11	0.03	0.04	0.03	0.03	0.03	0.03	0.03	30.2	397	0.70	1.34
	LTM	2000	11	0.05	0.06	0.05	0.03	0.03	0.03	0.03	30.6	464	0.36	1.55
	LTM	2001	11	0.05	0.08	0.06	0.03	0.03	0.03	0.03	34.0	657	0.94	1.46

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
MORROW POND														
CARP	MICH	1985	20	0.39	8.90	2.54	2.91		1.77		47.9	1481	1.61	1.34
	MICH	1986	20	0.60	12.69	3.46	4.67		3.33		46.9	1398	2.43	1.35
	MICH	1987	9	0.26	5.83	1.42	1.94		1.14		50.6	1589	1.33	1.22
	BBL	1993	11	0.08	1.90	0.61	0.93	1.12	0.59	0.55	62.0	3917	1.06	1.50
	BBL	1997	11	0.06	0.65	0.26	0.76	0.88	0.48	0.45	59.5	2982	0.44	1.33
	BBL	1999	11	0.17	1.04	0.49	0.60	0.64	0.39	0.39	59.4	3195	1.27	1.35
	LTM	1999	11	0.08	0.56	0.22	0.39	0.42	0.25	0.25	50.1	1515	1.10	1.17
	LTM	2001	11	0.16	2.00	0.73	0.74	0.75	0.44	0.29	54.9	2348	2.32	1.31
CHANNEL CATFISH	LTM	2001	1	0.34	0.34	0.34					54.7	1701	3.83	1.04
LARGEMOUTH BASS	MICH	1985	3	1.16	1.95	1.55					31.5	433	1.13	1.35
SMALLMOUTH BASS	MICH	1985	4	0.79	1.44	1.07	1.23		1.17		26.9	258	0.60	1.22
	MICH	1987	10	0.54	1.25	0.82	0.34		0.32		31.9	654	2.41	2.00
	BBL	1993	11	0.10	0.67	0.28	0.25	0.25	0.23	0.20	34.7	774	0.86	1.75
	BBL	1997	11	0.03	0.34	0.11	0.15	0.15	0.14	0.12	35.8	676	0.40	1.41
	BBL	1999	11	0.04	1.08	0.23	0.19	0.19	0.18	0.15	38.9	834	0.84	1.43
	LTM	1999	11	0.08	0.26	0.16	0.17	0.17	0.16	0.14	29.4	317	0.66	1.21
	LTM	2001	11	0.05	0.15	0.07	0.09	0.09	0.09	0.07	29.2	338	0.32	1.30

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

				Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)							
							Site-wide		ABSA-specific					
Species	Source[3]	Year	N	Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
DOWNSTREAM OF MORROW DAM														
CARP	BBL	1993	11	1.40	8.20	4.43	3.52	3.52	4.69	4.69	56.1	2989	3.54	1.65
	LTM	2000	6	1.30	6.21	2.98	1.78	1.78	2.38	2.38	55.4	2348	5.14	1.31
NORTHERN PIKE	LTM	2000	1	0.43	0.43	0.43					64.6	1474	0.33	0.55
ROCK BASS	LTM	2000	1	0.05	0.05	0.05					21.5	227	0.35	2.28
SMALLMOUTH BASS	BBL	1993	11	0.38	3.23	1.09	0.63	0.63	0.61	0.61	33.4	644	1.27	1.69
	LTM	2000	11	0.06	0.57	0.28	0.41	0.41	0.39	0.39	29.5	309	0.47	1.16
	LTM	2001	1	0.56	0.56	0.56					29.7	312	0.64	1.19

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
MOSEL AVENUE														
CARP	MICH	1983	11	0.98	6.53	3.15	2.89		3.80		46.9	1909	2.32	1.80
	MICH	1985	18	1.42	10.80	5.08	5.72		6.52		46.2	1675	2.00	1.68
	MICH	1986	20	1.48	11.09	4.68	3.23		3.99		46.7	1890	4.11	1.83
	BBL	1993	11	1.17	12.60	6.55	2.95	3.21	3.95	6.71	58.8	3706	6.10	1.78
	BBL	1999	11	2.23	21.70	6.48	1.40	2.57	2.17	5.38	59.2	3377	7.47	1.56
	LTM	2000	5	1.25	10.34	7.76	3.01	2.58	3.70	5.38	76.3	6311	13.83	1.42
PUMPKINSEED SUNFISH	BBL	1999	11	0.18	0.60	0.35					16.7	115	1.10	2.42
SMALLMOUTH BASS	MICH	1985	2	0.90	1.89	1.40	3.48		3.76		34.1	590	0.18	1.42
	BBL	1993	11	0.16	0.72	0.48	0.46	0.46	0.49	0.53	33.4	607	0.80	1.60
	BBL	1999	11	0.36	0.95	0.67	0.58	0.59	0.63	0.67	38.2	726	0.86	1.25
	LTM	2000	11	0.20	2.35	0.87	0.63	0.63	0.68	0.72	31.3	343	1.16	1.08

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
PLAINWELL DAM														
CARP	MICH	1983	11	0.88	15.90	5.47	5.02		8.24		50.6	1884	2.81	1.42
	MICH	1985	20	1.57	12.50	5.24	6.54		9.15		46.2	1416	2.40	1.44
	MICH	1986	21	0.50	9.46	4.13	4.49		6.27		47.0	1609	2.76	1.53
	MICH	1987	9	1.23	17.12	5.19	2.72		5.04		51.4	2331	4.52	1.67
	BBL	1993	11	1.44	17.20	5.81	2.28	2.47	3.96	8.88	56.5	3143	5.22	1.71
	BBL	1997	11	1.12	17.34	5.93	1.94	1.71	3.14	6.14	61.0	3700	5.69	1.51
	BBL	1999	11	5.05	16.45	9.93	2.69	1.84	4.00	6.63	67.9	4841	11.49	1.53
	LTM	1999	11	1.26	21.54	10.30	2.39	1.62	3.56	5.82	67.9	5479	11.71	1.67
	LTM	2001	11	1.36	20.65	9.80	1.73	1.74	3.01	6.26	67.8	4920	8.83	1.50
SMALLMOUTH BASS	MICH	1985	1	3.28	3.28	3.28					27.4	220	1.20	1.07
	BBL	1993	11	0.68	3.89	1.78	1.31	1.31	1.11	1.11	34.5	761	1.17	1.77
	BBL	1997	11	0.09	1.42	0.46	0.26	0.26	0.23	0.23	36.7	649	0.26	1.30
	BBL	1999	11	0.17	1.13	0.49	0.83	0.83	0.70	0.70	38.8	680	0.37	1.14
	LTM	1999	11	0.35	1.05	0.72	0.68	0.68	0.58	0.58	28.7	263	0.67	1.07
	LTM	2001	11	0.27	1.15	0.56	0.59	0.59	0.50	0.50	29.1	322	0.81	1.22

Note: See footnotes on page 17

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm^3
OTSEGO CITY DAM														
BLUEGILL SUNFISH	BBL	1999	11	0.05	0.78	0.28					17.4	108	0.75	1.94
CARP	BBL	1993	11	1.05	8.03	3.44	2.75	2.75	3.00	3.00	56.1	3025	2.86	1.70
	LTM	1999	11	0.49	2.68	1.11	1.12	1.12	1.22	1.22	47.9	1513	2.31	1.37
	LTM	2001	11	0.30	7.62	2.84	2.05	2.05	2.24	2.24	56.4	2974	2.26	1.53
CHANNEL CATFISH	BBL	1999	2	4.74	5.40	5.07					63.5	2625	3.50	1.03
NORTHERN PIKE	BBL	1999	2	0.06	0.84	0.45					65.6	2260	0.55	0.73
SMALLMOUTH BASS	BBL	1993	11	0.27	3.66	0.99	1.07	1.07	1.08	1.08	34.6	837	1.56	1.96
	LTM	1999	11	0.13	1.47	0.52	0.47	0.47	0.48	0.48	32.1	457	0.65	1.24
	BBL	1999	11	0.16	2.47	1.04	1.11	1.11	1.12	1.12	40.0	868	0.91	1.27
	LTM	2001	11	0.05	1.24	0.46	1.02	1.02	0.98	0.98	28.9	405	0.42	1.69
WALLEYE	BBL	1999	1	0.89	0.89	0.89					60.6	1950	0.70	0.88

Note: See footnotes on page 17

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg) Site-wide		Adjusted[1,2] PCB (mg/kg) ABSA-specific		Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
				Min	Max	Avg.	Model I[4]	Model II	Model I	Model II				
OTSEGO DAM														
CARP	BBL	1993	11	0.56	6.40	2.69	2.61	2.61	3.66	3.66	55.1	2874	2.33	1.65
	LTM	1999	11	0.29	4.86	2.54	1.69	1.69	2.37	2.37	55.7	2399	2.93	1.36
	LTM	2001	11	1.40	49.54	9.00	2.54	2.54	3.56	3.56	58.9	2809	5.38	1.29
SMALLMOUTH BASS	BBL	1993	11	0.39	3.73	1.48	1.24	1.24	1.03	1.03	36.4	853	0.86	1.69
	LTM	1999	11	0.31	1.15	0.58	0.59	0.59	0.58	0.58	33.6	482	0.48	1.19
	LTM	2001	11	0.32	1.09	0.63	0.60	0.60	0.62	0.62	31.2	374	0.58	1.17

Note: See footnotes on page 17

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Model II	ABSA-specific Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
TROWBRIDGE DAM														
BLUEGILL SUNFISH	BBL	1999	11	0.07	0.55	0.31					17.9	113	0.59	1.97
CARP	BBL	1993	11	1.31	9.60	4.55	5.13	5.13	4.82	4.82	58.2	3042	1.63	1.52
	BBL	1999	11	0.64	5.15	2.68	3.03	3.03	2.85	2.85	57.0	2836	4.92	1.43
	LTM	1999	11	0.93	16.01	3.66	3.25	3.25	3.05	3.05	51.2	1977	2.07	1.35
	LTM	2001	11	1.18	7.26	3.99	3.31	3.31	3.10	3.10	51.7	1959	2.84	1.39
CHANNEL CATFISH	BBL	1999	3	1.53	2.18	1.80					58.5	2167	3.53	1.05
	LTM	1999	1	5.09	5.09	5.09					65.1	2863	5.70	1.04
NORTHERN PIKE	BBL	1999	2	1.02	1.41	1.22					79.8	4000	0.65	0.66
SMALLMOUTH BASS	BBL	1993	11	0.74	4.19	1.95	1.68	1.68	1.59	1.59	33.5	618	0.88	1.61
	BBL	1999	11	0.39	1.42	0.73	0.96	0.96	0.91	0.91	37.6	651	0.50	1.20
	LTM	1999	11	0.47	1.63	1.14	1.15	1.15	1.09	1.09	34.2	510	0.70	1.18
	LTM	2001	11	0.60	2.77	1.15	1.04	1.04	0.99	0.99	33.9	573	0.79	1.31
WALLEYE	BBL	1999	1	0.64	0.64	0.64					50.5	1200	0.80	0.93

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

				Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)							
							Site-wide		ABSA-specific					
Species	Source[3]	Year	N	Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm^3
CITY OF ALLEGAN DAM														
CARP	LTM	1999	11	0.43	7.25	3.34					55.8	2518	3.85	1.39
	LTM	2001	11	0.95	6.41	3.96					53.3	2142	3.81	1.39
SMALLMOUTH BASS	LTM	1999	11	0.14	0.93	0.56					29.7	392	0.50	2.37
	LTM	2001	11	0.17	0.89	0.52					31.3	430	0.62	1.34

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
LAKE ALLEGAN														
BLACK CRAPPIE	BBL	1999	1	1.16	1.16	1.16					23.1	172	1.80	1.40
	LTM	2000	1	0.40	0.40	0.40					28.0	454	0.57	2.07
BLUEGILL SUNFISH	BBL	1999	8	0.20	0.70	0.39					17.2	104	0.68	1.98
CARP	MICH	1983	3	1.60	5.03	2.77					44.5	1134	0.80	1.28
	MICH	1985	19	1.53	14.00	4.43	7.38		3.05		41.5	1043	1.59	1.45
	MICH	1986	81	0.09	23.95	4.27	12.54		3.72		38.9	850	1.18	1.31
	MICH	1987	10	1.21	6.14	3.18	9.40		3.32		40.1	864	1.04	1.33
	MICH	1990	10	1.36	5.87	3.73	6.32	6.16	2.94	3.25	39.5	868	1.67	1.41
	MICH	1992	9	0.20	7.72	4.02	6.92	6.77	1.83	1.99	41.4	1026	1.74	1.44
	BBL	1993	11	0.10	6.50	1.77	3.28	3.24	1.18	1.31	46.2	1541	1.35	1.57
	MICH	1994	10	0.57	6.50	1.84	7.16	6.98	2.16	2.36	40.2	919	0.92	1.41
	BBL	1997	11	0.26	1.65	0.72	2.00	1.99	0.97	1.09	48.1	1418	0.55	1.26
	BBL	1999	11	0.29	5.62	1.74	1.72	1.74	1.09	1.27	56.6	2427	1.00	1.26
	LTM	1999	11	0.21	1.30	0.69	0.85	0.85	0.54	0.62	47.9	1660	1.42	1.30
	LTM	2000	11	0.05	4.28	0.98	5.96	5.92	1.19	1.30	46.6	1278	0.88	1.26
	LTM	2001	11	0.49	2.92	1.49	1.59	1.59	0.73	0.83	51.7	2026	1.86	1.34
CHANNEL CATFISH	BBL	1999	11	0.24	2.87	1.09					39.2	537	1.19	0.87
	LTM	1999	1	0.55	0.55	0.55					41.5	510	1.20	0.71
	LTM	2001	6	0.61	3.77	2.17					39.7	591	1.45	0.91
LARGEMOUTH BASS	MICH	1983	2	0.39	0.44	0.42					40.0	1000		1.56
	MICH	1985	7	0.67	6.54	3.09					33.7	533	1.07	1.37

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Wet Weight PCB (mg/kg) Max	Wet Weight PCB (mg/kg) Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Adjusted[1,2] PCB (mg/kg) Site-wide Model II	Adjusted[1,2] PCB (mg/kg) ABSA-specific Model I	Adjusted[1,2] PCB (mg/kg) ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm^3
LAKE ALLEGAN														
LARGEMOUTH BASS	LTM	2000	1	0.31	0.31	0.31					44.0	1304	0.36	1.53
NORTHERN PIKE	MICH	1987	3	1.71	3.09	2.36					79.7	3167	0.67	0.63
	BBL	1999	11	0.32	4.60	1.81					78.9	3342	1.05	0.65
PUMPKINSEED SUNFISH	BBL	1999	3	0.27	0.55	0.41					16.1	85	0.67	2.04
SMALLMOUTH BASS	MICH	1985	3	1.90	2.42	2.12	1.95		1.94		33.1	550	0.50	1.45
	MICH	1987	10	1.39	5.14	3.05	2.09		2.16		37.6	1106	1.07	2.02
	BBL	1993	11	1.58	5.80	3.29	1.15	1.15	1.18	1.16	36.0	998	2.92	2.02
	BBL	1997	11	0.16	1.58	0.49	0.56	0.56	0.56	0.56	37.0	656	0.49	1.28
	BBL	1999	10	0.15	0.89	0.56	0.57	0.57	0.57	0.57	31.9	414	0.67	1.24
	LTM	1999	11	0.33	0.83	0.55	0.54	0.54	0.54	0.54	29.2	304	0.90	1.19
	LTM	2000	10	0.10	0.80	0.35	0.50	0.50	0.51	0.50	28.9	315	0.50	1.26
	LTM	2001	11	0.15	0.84	0.49	0.58	0.58	0.61	0.59	28.1	289	0.59	1.30
SUNFISH	MICH	1983	1	0.48	0.48	0.48					19.7	153		2.00
WALLEYE	BBL	1999	11	0.18	1.53	0.76					45.9	1002	0.92	0.99
	LTM	2000	2	0.32	1.80	1.06					51.7	1871	1.20	1.52

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)				Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
							Site-wide		ABSA-specific					
				Min	Max	Avg.	Model I[4]	Model II	Model I	Model II				
DOWNSTREAM OF ALLEGAN DAM														
CARP	BBL	1993	11	1.93	17.00	7.60					62.5	5861	10.38	2.01
SMALLMOUTH BASS	BBL	1993	11	1.05	2.42	1.89					35.7	962	1.77	2.03

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
NEW RICHMOND														
CARP	BBL	1993	11	1.39	9.10	4.95	7.45	7.45	5.90	5.90	58.7	4348	8.14	1.90
	BBL	1997	12	0.36	17.30	4.72	1.95	1.95	3.28	3.28	57.7	3183	6.45	1.56
	BBL	1999	11	1.97	6.87	3.53	1.93	1.93	2.94	2.94	60.9	3575	5.62	1.46
	LTM	1999	10	0.20	4.06	1.58	1.17	1.17	1.78	1.78	54.6	2517	4.85	1.37
	LTM	2001	11	0.48	5.80	2.34	2.12	2.12	3.60	3.60	51.2	1799	2.40	1.32
CHANNEL CATFISH	BBL	1999	1	1.61	1.61	1.61					34.1	355	4.50	0.90
	LTM	1999	1	1.70	1.70	1.70					56.7	1474	2.35	0.81
FLATHEAD CATFISH	LTM	2001	4	0.60	3.32	1.96					74.6	5209	0.98	1.14
LARGEMOUTH BASS	LTM	1999	2	0.81	1.09	0.95					37.3	794	1.03	1.43
NORTHERN PIKE	BBL	1999	4	0.33	0.46	0.39					67.5	1818	0.53	0.58
SMALLMOUTH BASS	BBL	1993	11	0.13	0.83	0.54	0.49	0.49	0.49	0.49	29.5	538	0.87	1.85
	BBL	1997	11	0.20	4.30	1.07	1.25	1.25	1.25	1.25	37.8	859	0.52	1.57
	BBL	1999	11	0.05	2.72	0.73	0.77	0.77	0.77	0.77	34.2	484	0.81	1.15
	LTM	1999	7	0.31	1.45	0.67	0.52	0.52	0.52	0.52	33.7	571	1.25	1.29
	LTM	2001	10	0.28	0.89	0.59	0.60	0.60	0.60	0.60	30.5	403	0.67	1.36
WALLEYE	BBL	1999	11	0.03	0.92	0.28					47.8	1212	1.44	1.01

Note: See footnotes on page 17

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm^3
SAUGATUCK														
BLACK CRAPPIE	MICH	1987	10	0.30	1.59	0.70					26.0	315	0.82	1.73
BLUEGILL	MICH	1987	10	0.19	0.68	0.43					18.3	169	1.08	2.72
BROWN TROUT	MICH	1987	4	1.32	4.62	3.73					52.1	1855	9.33	1.31
	LTM	1999	1	0.90	0.90	0.90					60.0	2466	6.55	1.14
CARP	MICH	1984	11	1.03	25.70	8.49	1.97		5.86		50.3	1769	5.60	1.35
	MICH	1985	20	0.20	9.12	3.59	3.24		7.00		47.9	1602	5.51	1.45
	MICH	1986	24	0.51	10.50	4.26	1.56		3.08		52.3	2335	7.71	1.52
	MICH	1987	9	1.02	8.64	4.45	2.33		3.96		50.9	1983	5.69	1.48
	BBL	1999	11	0.71	3.40	1.81	1.31	1.33	1.71	1.68	57.3	2791	6.01	1.42
	LTM	1999	11	0.69	6.48	2.69	1.61	1.69	2.10	2.12	58.5	3044	11.39	1.46
	LTM	2001	11	0.06	3.84	1.63	0.83	0.87	1.20	2.64	54.6	2214	2.10	1.34
CHANNEL CATFISH	MICH	1987	8	3.45	12.41	6.36					50.6	1615	10.09	1.14
	BBL	1999	4	0.30	4.80	2.53					58.3	2488	11.05	1.22
	LTM	2001	2	3.00	3.83	3.41					50.6	2070	2.00	1.69
FLTH. CATFISH	MICH	1987	3	1.71	22.20	13.71					79.6	5953	3.61	1.12
FRESHWATER DRUM	MICH	1987	2	0.54	1.78	1.16					37.1	840	3.90	1.48
LARGEMOUTH BASS	MICH	1985	9	0.48	2.97	1.33					35.4	707	0.79	1.54
	MICH	1986	5	0.06	1.09	0.56					37.3	866	0.82	1.58

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
SAUGATUCK														
LARGEMOUTH BASS	MICH	1987	10	0.52	2.02	1.10					35.2	806	0.89	1.77
NORTHERN PIKE	MICH	1987	10	0.36	3.36	1.33					60.2	1654	1.60	0.68
	BBL	1999	4	0.09	0.51	0.26					64.0	1788	0.90	0.68
RAINBOW TROUT	MICH	1987	10	0.24	0.73	0.44					59.9	2702	6.97	1.22
ROCK BASS	MICH	1987	10	0.17	0.52	0.37					18.1	154	0.53	2.60
SMALLMOUTH BASS	MICH	1985	1	1.71	1.71	1.71					29.5	280	0.90	1.09
	BBL	1999	11	0.16	0.65	0.32	0.22	0.22	0.30	0.30	38.9	1000	1.38	1.63
	LTM	1999	11	0.20	1.16	0.53	0.33	0.33	0.45	0.45	40.4	1144	1.89	1.48
	LTM	2001	11	0.26	1.18	0.54	0.45	0.45	0.61	0.61	33.1	606	1.62	1.46
WALLEYE	MICH	1987	10	0.33	1.48	0.58					44.6	1036	1.38	1.13
	BBL	1999	8	0.07	0.39	0.18					48.7	1428	0.95	1.10
WHITE SUCKER	MICH	1987	10	0.44	2.82	1.08					47.7	1364	3.15	1.23
YELLOW PERCH	MICH	1987	10	0.06	1.20	0.43					18.9	109	0.46	1.57
SAUGATUCK RIVER MOUTH														
CARP	MICH	1993	5	1.09	1.09	1.09					51.6	2282	4.75	1.62

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Wet Weight PCB (mg/kg) Max	Wet Weight PCB (mg/kg) Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Adjusted[1,2] PCB (mg/kg) Site-wide Model II	Adjusted[1,2] PCB (mg/kg) ABSA-specific Model I	Adjusted[1,2] PCB (mg/kg) ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] $10,000xg/cm^3$
VARIOUS														
WALLEYE	MICH	1993	13	0.17	3.71	1.01					50.3	1299	1.14	0.96
MONARCH MILL POND														
CARP	LTM	2001	11	0.05	0.47	0.18					62.0	3428	2.16	1.41
FORMER BRYANT MILL POND														
BROWN TROUT	LTM	2000	1	0.05	0.05	0.05					22.0	98	0.80	0.92
CARP	MICH	1985	10	1.57	4.50	3.04	10.01		4.65		45.5	1334	0.60	1.40
	MICH	1986	21	0.81	27.37	3.97	5.78		2.68		46.2	1452	1.21	1.44
	MICH	1987	10	0.54	5.50	1.92	4.32		2.01		50.0	1847	0.83	1.43
	BBL	1993	11	1.52	8.79	3.42	4.56		2.12		50.5	1955	1.51	1.49
	LTM	2000	11	0.05	1.25	0.36	0.30		0.30		55.2	2580	2.12	1.51
	LTM	2001	11	0.13	3.66	0.72	0.44		0.44		53.4	2477	3.02	1.61

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

				Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)							
							Site-wide		ABSA-specific					
Species	Source[3]	Year	N	Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm^3

Notes:
1) Concentrations below detection were replaced with half the detection limits.
2) Adjusted PCB concentrations account for covariation between PCB, lipid and length so that carp are adjusted to geometric mean length (50.9 cm) and lipid (1.97%) and Smallmouth Bass are adjusted to geometric mean length (33.1 cm) and lipid (0.70%).
3) Data Sources include MICH (Michigan Department of Community Health), BBL (Blasland Bouck and Lee for Kalamazoo river Study Group), and LTM (MichiganDepartment of Environmental Quality long term monitoring program).
4) Model I adjustements are based on fish collected from 1983 through 2001. Model II adjustments exclude fish collected prior to 1990.
5) Condition index is 10,000 times mass in grams divided by length cubed.

Note: See footnotes on page 17

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

ABSA WHERE FILLET PCB CONCENTRATION WAS CORRELATED WITH
LIPID FRACTION AND OR FISH LENGTH AT THE 0.05 LEVEL OF SIGNIFICANCE

ABSA Name	Species	Lipid	Length
BATTLE CREEK	Carp	X	
	Smallmouth	X	X
MORROW POND	Carp	X	X
	Smallmouth	X	
DOWNSTREAM OF MORROW DAM	Carp	X	
	Smallmouth	X	
MOSEL AVENUE	Carp	X	
	Smallmouth	X	
PLAINWELL DAM	Carp	X	X
	Smallmouth	X	X
OTSEGO CITY DAM	Carp	X	X
	Smallmouth	X	
OTSEGO DAM	Carp	X	
	Smallmouth	X	
TROWBRIDGE DAM	Carp	X	
	Smallmouth	X	
LAKE ALLEGAN	Carp	X	X
	Smallmouth	X	
NEW RICHMOND	Carp	X	
	Smallmouth	X	
SAUGATUCK	Carp	X	X
	Smallmouth	X	X
FORMER BRYANT MILL POND	Carp	X	

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
BATTLE CREEK									
Carp									
intercept	Intercept	-2.88	0.24			-1.45	0.26		
Year	1991	1.44	0.35						
	1993	0.32	0.29			-1.12	0.31		
	1997	0.66	0.32			-0.78	0.34		
	1999	-0.40	0.41			-1.84	0.43		
	2000	0.10	0.48			-1.34	0.50		
	2001	1.82	0.41			0.38	0.43		
Lipid	Lipid	0.82	0.24			1.66	0.46		
Lipid*Year	Lipid*1991	0.84	0.51	2.71	0.022				
	Lipid*1993	-0.48	0.36			-1.32	0.54	2.93	0.021
	Lipid*1997	0.23	0.42			-0.61	0.59		
	Lipid*1999	-0.01	0.42			-0.85	0.58		
	Lipid*2000	0.20	0.44			-0.64	0.60		
	Lipid*2001	-0.88	0.36			-1.72	0.54		
Smallmouth Bass									
Intercept	Intercept					-213.88	58.85		
Year	1993					214.29	59.01		
	1997					203.23	59.10		
	1999					209.97	58.90		
	2000					210.50	58.88		
	2001					207.26	58.93		
Lipid	Lipid					7.78	1.57		
Length	Length					62.96	17.50		
Lipid*Year	Lipid*1993					-6.51	1.59	5.81	<0.001
	Lipid*1997					-7.58	1.58		
	Lipid*1999					-7.73	1.60		
	Lipid*2000					-7.78	1.58		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Parameter	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
BATTLE CREEK									
Smallmouth Bass									
Lipid*Year	Lipid*2001					-7.63	1.59	5.81	<0.001
Length*Year	Length*1983					-63.77	17.54	3.23	0.014
	Length*1997					-60.84	17.57		
	Length*1999					-62.85	17.52		
	Length*2001					-62.06	17.52		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
MORROW POND									
Carp									
intercept	Intercept	4.50	9.99			-1.29	5.26		
Year	1986	-24.09	15.57						
	1987	4.90	14.25						
	1993	-7.73	11.39						
	1997	-7.28	11.01			-1.50	6.69		
	1999	-13.99	10.39			-8.91	6.17		
	2001	2.76	10.89			9.27	6.28		
Lipid	Lipid	0.81	0.08	91.4	<0.001	0.91	0.12	43.3	<0.001
Length	Length	-1.04	2.58			0.18	1.27		
Length*Year	Length*1986	6.23	4.04	2.39	0.034				
	Length*1987	-1.38	3.66						
	Length*1983	1.69	2.90						
	Length*1997	1.52	2.82			0.33	1.64	4.58	0.006
	Length*1999	3.10	2.68			2.06	1.50		
	Length*2001	-1.05	2.80			-2.47	1.53		
Smallmouth Bass									
intercept	Intercept	0.43	0.29			-1.24	0.19		
Year	1987	-1.27	0.40						
	1993	-1.66	0.33						
	1997	-2.26	0.33			-0.59	0.29		
	1999	-2.11	0.30			-0.44	0.23		
	2001	-2.67	0.35			-1.01	0.32		
Lipid	Lipid	0.71	0.16	20.4	<0.001	0.71	0.18	15.9	<0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

			Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
DOWNSTREAM OF MORROW DAM										
Carp										
	Intercept	Intercept					0.81	0.26		
	Year	2000					-0.63	0.24		
	Lipid	Lipid					0.51	0.20	6.72	0.021
Smallmouth Bass										
	Intercept	Intercept					-0.19	0.15		
	Year	2000					-0.53	0.28		
	Lipid	Lipid					0.90	0.19	22.7	<0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
MOSEL AVENUE									
Carp									
intercept	Intercept	0.54	0.14			0.69	0.16		
Year	1985	0.94	0.17						
	1986	0.21	0.20						
	1993	0.00	0.27						
	1999	-1.02	0.53			-0.28	0.16		
	2000	0.21	0.30			-0.21	0.20		
Lipid	Lipid	0.69	0.15			0.65	0.08	68.4	<0.001
Lipid*Year	Lipid*1985	-0.36	0.17	3.15	0.013				
	Lipid*1986	-0.15	0.18						
	Lipid*1993	0.05	0.20						
	Lipid*1999	0.42	0.30						
	Lipid*2000	-0.17	0.19						
Smallmouth Bass									
intercept	Intercept	1.47	0.38			-0.58	0.13		
Year	1993	-2.04	0.37						
	1999	-1.80	0.38			0.24	0.17		
	2000	-1.80	0.40			0.25	0.17		
Lipid	Lipid	0.70	0.15	20.7	<0.001	0.68	0.15	19.6	<0.001

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Parameter	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
PLAINWELL DAM									
Carp									
intercept	Intercept	-7.46	2.19			-12.04	2.12		
Year	1985	0.49	0.20						
	1986	0.09	0.21						
	1987	-0.67	0.33						
	1993	-0.79	0.38						
	1997	-0.82	0.27			-0.31	0.15		
	1999	-0.48	0.41			-0.34	0.15		
	2001	-1.06	0.42			-0.33	0.16		
Lipid	Lipid	0.61	0.12			0.49	0.08	106.	<0.001
Length	Length	2.17	0.56			3.19	0.54	33.4	<0.001
Lipid*Year	Lipid*1985	-0.29	0.15	2.58	0.017				
	Lipid*1986	-0.29	0.17						
	Lipid*1987	0.22	0.25						
	Lipid*1993	0.10	0.26						
	Lipid*1997	-0.02	0.19						
	Lipid*1999	-0.18	0.20						
	Lipid*2001	0.11	0.23						
Smallmouth Bass									
Intercept	Intercept					0.40	4.53		
Year	1997					-38.06	16.15		
	1999					2.05	4.91		
	2001					-4.94	5.36		
Lipid	Lipid					0.63	0.16	27.1	<0.001
Length	Length					0.01	1.28		
Length*Year	Length*1997					10.41	4.47	2.97	0.041
	Length*1999					-0.76	1.39		
	Length*2001					1.19	1.54		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
PLAINWELL DAM								
Smallmouth Bass								

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Parameter	Model I Based on 1983 - 2001 Estimate	Stderr	F	Significance	Model II Based on 1990 - 2001 Estimate	Stderr	F	Significance
OTSEGO CITY DAM										
Carp										
	Intercept	Intercept					-7.33	3.90		
	Year	1999					-0.74	0.31		
		2001					-0.22	0.27		
	Lipid	Lipid					0.51	0.17	10.6	0.002
	Length	Length					1.98	0.97	4.99	0.034
Smallmouth Bass										
	Intercept	Intercept					-0.26	0.27		
	Year	1999					-0.44	0.35		
		2001					0.73	0.55		
	Lipid	Lipid					-0.13	0.42		
	Lipid*Year	Lipid*1999					-0.12	0.55	6.98	0.002
		Lipid*2001					1.67	0.57		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

			Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
OTSEGO DAM										
Carp										
	Intercept	Intercept					0.06	0.18		
	Year	1999					-0.29	0.22		
		2001					0.11	0.25		
	Lipid	Lipid					1.04	0.14	51.5	<0.001
Smallmouth Bass										
	Intercept	Intercept					0.49	0.13		
	Year	1999					-1.05	0.38		
		2001					-1.13	0.22		
	Lipid	Lipid					0.92	0.20		
	Lipid*Year	Lipid*1999					-0.87	0.48	6.86	0.003
		Lipid*2001					-1.08	0.30		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
TROWBRIDGE DAM									
Carp									
Intercept	Intercept					1.25	0.19		
Year	1999					-0.61	0.23		
	2001					-0.40	0.28		
Lipid	Lipid					0.41	0.11	14.4	<0.001
Smallmouth Bass									
Intercept	Intercept					0.78	0.10		
Year	1999					-0.49	0.13		
	2001					-0.49	0.14		
Lipid	Lipid					0.79	0.12	42.8	<0.001

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
LAKE ALLEGAN									
Carp									
intercept	Intercept	-4.53	1.19			-4.11	2.47		
Year	1986	0.16	0.17						
	1987	0.13	0.24						
	1990	0.05	0.28						
	1992	-0.59	0.29			-0.63	0.39		
	1993	-1.10	0.24			-1.13	0.36		
	1994	-0.41	0.25			-0.45	0.36		
	1997	-1.14	0.33			-1.16	0.45		
	1999	-1.48	0.21			-1.50	0.36		
	2000	-1.37	0.25			-1.39	0.37		
	2001	-1.42	0.29			-1.44	0.43		
Lipid	Lipid	0.93	0.25			0.75	0.43		
Length	Length	1.48	0.32			1.38	0.67		
Lipid*Year	Lipid*1986	0.51	0.27	3.79	<0.001				
	Lipid*1987	0.24	0.59						
	Lipid*1990	-0.18	0.45						
	Lipid*1992	0.69	0.43			0.87	0.59	2.82	0.011
	Lipid*1993	0.22	0.38			0.39	0.54		
	Lipid*1994	0.48	0.57			0.66	0.73		
	Lipid*1997	-0.24	0.37			-0.06	0.53		
	Lipid*1999	-0.66	0.31			-0.48	0.48		
	Lipid*2000	1.12	0.45			1.30	0.60		
	Lipid*2001	-0.17	0.41			0.01	0.57		
Smallmouth Bass									
intercept	Intercept	0.62	0.39			0.37	0.33		
Year	1987	0.41	0.41						
	1993	-0.25	0.50						

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
LAKE ALLEGAN									
Smallmouth Bass									
Year	1997	-1.25	0.46			-1.00	0.42		
	1999	-1.25	0.40			-1.00	0.35		
	2000	-1.05	0.47			-0.80	0.43		
	2001	-0.80	0.43			-0.56	0.39		
Lipid	Lipid	-0.14	0.34			0.75	0.31		
Lipid*Year	Lipid*1987	1.06	0.48	3.49	0.004				
	Lipid*1993	0.89	0.45						
	Lipid*1997	0.47	0.41			-0.41	0.40	3.63	0.010
	Lipid*1999	0.24	0.37			-0.65	0.35		
	Lipid*2000	1.09	0.43			0.20	0.42		
	Lipid*2001	1.19	0.41			0.30	0.39		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

			Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
NEW RICHMOND										
Carp										
	Intercept	Intercept					2.09	0.65		
	Year	1997					-2.29	0.79		
		1999					-2.29	0.71		
		2001					-2.14	0.72		
	Lipid	Lipid					-0.37	0.33		
	Lipid*Year	Lipid*1997					1.19	0.42	3.31	0.027
		Lipid*1999					1.04	0.38		
		Lipid*2001					1.21	0.47		
Smallmouth Bass										
	Intercept	Intercept					-0.64	0.22		
	Year	1997					0.58	0.33		
		1999					0.11	0.27		
		2001					0.24	0.32		
	Lipid	Lipid					0.45	0.22	3.99	0.051

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
SAUGATUCK									
Carp									
intercept	Intercept	-0.68	6.27			-1.25	6.79		
Year	1985	-36.57	13.66						
	1986	2.79	7.42						
	1987	4.53	11.03						
	1999	-0.08	8.54						
	2001	-35.63	11.91			-33.38	12.83		
Lipid	Lipid	1.31	0.24			0.27	0.17	5.13	0.030
Length	Length	0.09	1.63			0.34	1.70		
Lipid*Year	Lipid*1985	-0.68	0.33	2.60	0.030				
	Lipid*1986	-0.47	0.30						
	Lipid*1987	-0.64	0.36						
	Lipid*1999	-1.00	0.29						
	Lipid*2001	-1.15	0.36						
Length*Year	Length*1985	9.56	3.57	4.21	0.001				
	Length*1986	-0.70	1.94						
	Length*1987	-0.99	2.86						
	Length*1999	0.10	2.19						
	Length*2001	9.00	3.03			8.33	3.20	6.78	0.014
Smallmouth Bass									
Intercept	Intercept					-5.97	1.27		
Year	2001					0.54	0.15		
Lipid	Lipid					0.22	0.16	4.76	0.037
Length	Length					1.34	0.35	13.1	0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
FORMER BRYANT MILL POND									
Carp									
intercept	Intercept	1.66	0.22			0.66	0.28		
Year	1986	-0.67	0.26						
	1987	-0.90	0.29						
	1993	-0.97	0.31						
	2000	-4.02	0.33			-3.09	0.37		
	2001	-3.51	0.35			-2.60	0.39		
Lipid	Lipid	1.07	0.15	52.3	<0.001	1.17	0.31	14.2	<0.001

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA [2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
BATTLE CREEK													
CARP	1983-2001	ABSA-specific	-1.8	-9.3	6.3	0.747	1.45	-1.00	2.39	0.822	0.82	0.62	1.30
	1983-2001	Site-wide	-1.3	-10.4	10.0	0.699	0.21	-1.00	2.24	0.978	0.83	0.65	1.48
	1990-2001	ABSA-specific	2.7	-13.7	38.1	0.291	1.78	-0.26	3.47	0.210	0.85	0.59	1.34
	1990-2001	Site-wide	3.9	-16.7	75.6	0.192	1.26	-0.22	3.18	0.186	0.85	0.62	1.40
SMALLMOUTH BASS	1990-2001	ABSA-specific	9.4	3.0	18.7	0.002	-0.35	-0.81	0.54	0.312	0.31	0.19	0.37
	1990-2001	Site-wide	10.4	4.2	18.9	<0.001	-0.31	-0.61	0.58	0.448	0.31	0.19	0.36
MORROW POND													
CARP	1983-2001	ABSA-specific	10.0	4.8	19.0	<0.001	0.49	-0.22	0.65	0.148	0.60	0.44	0.99
	1983-2001	Site-wide	10.1	5.9	16.3	<0.001	0.50	-0.11	0.64	0.122	0.58	0.44	0.80
	1990-2001	ABSA-specific	10.3	2.7	20.2	0.004	-0.31	-0.58	1.34	0.904	0.46	0.34	0.53
	1990-2001	Site-wide	9.6	0.2	26.9	0.02	0.52	-0.19	2.35	0.104	0.50	0.38	0.58
SMALLMOUTH BASS	1983-2001	ABSA-specific	16.3	9.5	24.6	<0.001	0.51	-0.24	0.74	0.256	0.58	0.49	0.67
	1983-2001	Site-wide	16.3	9.7	24.0	<0.001	0.51	-0.24	0.75	0.256	0.58	0.49	0.67
	1990-2001	ABSA-specific	11.2	4.8	19.6	0.001	-0.29	-0.50	0.81	0.568	0.60	0.48	0.70
	1990-2001	Site-wide	11.2	5.0	18.2	0.001	-0.29	-0.53	0.80	0.556	0.60	0.48	0.70
DOWNSTREAM OF MORROW DAM													
CARP	1990-2001	ABSA-specific	7.9	2.3	15.1	<0.001	0.20	0.14	0.20	0.000	0.41	0.24	0.46
	1990-2001	Site-wide	7.9	2.6	13.9	<0.001	0.01	0.01	0.01	0.000	0.41	0.24	0.46
SMALLMOUTH BASS	1990-2001	ABSA-specific	7.5	1.0	13.6	0.015	0.21	-0.16	0.49	0.102	0.46	0.28	0.55
	1990-2001	Site-wide	7.5	1.0	13.5	0.015	0.01	0.01	0.01	0.000	0.46	0.28	0.55

Note: See footnotes on page 4

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA[2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
MOSEL AVENUE													
CARP	1983-2001	ABSA-specific	3.4	1.0	5.0	0.009	-0.70	-1.00	3.21	0.334	0.41	0.32	0.53
	1983-2001	Site-wide	4.2	0.6	6.3	0.016	-0.55	-1.00	2.83	0.356	0.45	0.36	0.63
	1990-2001	ABSA-specific	3.9	0.3	9.0	0.02	1.21	-1.00	2.37	0.576	0.33	0.19	0.41
	1990-2001	Site-wide	3.9	0.3	7.8	0.02	1.21	-1.00	2.37	0.620	0.33	0.19	0.41
SMALLMOUTH BASS	1983-2001	ABSA-specific	9.8	3.2	17.3	<0.001	0.83	0.56	2.05	0.000	0.50	0.38	0.63
	1983-2001	Site-wide	9.8	3.0	20.3	0.002	0.83	0.44	2.21	0.048	0.50	0.38	0.70
	1990-2001	ABSA-specific	-3.6	-8.3	0.0	0.976	-1.00	-1.00	1.23	0.974	0.36	0.24	0.45
	1990-2001	Site-wide	-3.5	-8.6	0.0	0.976	-1.00	-1.00	1.35	0.982	0.36	0.24	0.45
PLAINWELL DAM													
CARP	1983-2001	ABSA-specific	5.4	1.9	9.3	0.003	1.22	-0.60	3.22	0.244	0.46	0.33	0.55
	1983-2001	Site-wide	5.8	1.9	8.2	0.003	1.12	-0.52	2.94	0.344	0.48	0.37	0.60
	1990-2001	ABSA-specific	4.7	-0.1	9.1	0.026	1.03	-0.93	4.09	0.212	0.33	0.27	0.36
	1990-2001	Site-wide	4.6	-0.1	8.4	0.026	-0.02	-0.93	3.90	0.632	0.33	0.27	0.36
SMALLMOUTH BASS	1990-2001	ABSA-specific	8.5	0.8	17.4	0.018	0.59	-0.29	2.23	0.100	0.63	0.36	1.00
	1990-2001	Site-wide	8.5	0.8	16.7	0.019	0.59	-0.30	2.31	0.102	0.63	0.36	1.01
OTSEGO CITY DAM													
CARP	1990-2001	ABSA-specific	5.4	-1.2	14.7	0.055	0.88	0.05	3.55	0.048	0.63	0.45	0.72
	1990-2001	Site-wide	5.4	-1.2	14.7	0.055	0.88	-0.01	3.49	0.054	0.63	0.45	0.72
SMALLMOUTH BASS	1990-2001	ABSA-specific	1.8	-6.5	14.6	0.402	2.62	0.20	4.16	0.026	0.78	0.59	0.89
	1990-2001	Site-wide	1.5	-6.7	13.8	0.431	3.16	0.01	4.08	0.032	0.78	0.59	0.89

Note: See footnotes on page 4

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA [2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
OTSEGO DAM													
CARP	1990-2001	ABSA-specific	0.0	-7.9	8.2	0.47	0.20	0.20	5.22	0.000	0.51	0.29	0.64
	1990-2001	Site-wide	0.0	-8.8	7.8	0.47	0.06	0.02	5.12	0.002	0.51	0.29	0.64
SMALLMOUTH BASS	1990-2001	ABSA-specific	7.3	3.2	13.3	<0.001	0.65	-0.62	1.32	0.294	0.34	0.24	0.39
	1990-2001	Site-wide	10.3	6.2	15.7	<0.001	0.46	-0.41	0.72	0.394	0.34	0.24	0.41
TROWBRIDGE DAM													
CARP	1990-2001	ABSA-specific	7.5	1.8	14.2	0.01	0.67	-0.48	1.96	0.136	0.61	0.44	0.72
	1990-2001	Site-wide	7.5	1.8	14.3	0.01	0.67	-0.48	1.96	0.140	0.61	0.43	0.72
SMALLMOUTH BASS	1990-2001	ABSA-specific	7.3	4.2	11.0	<0.001	0.67	-0.54	1.06	0.238	0.32	0.24	0.37
	1990-2001	Site-wide	7.3	4.2	10.8	<0.001	0.67	-0.54	1.06	0.262	0.32	0.24	0.37
LAKE ALLEGAN													
CARP	1983-2001	ABSA-specific	8.6	7.3	10.0	<0.001	-0.10	-0.27	0.39	0.554	0.58	0.48	0.66
	1983-2001	Site-wide	9.8	7.5	13.5	<0.001	-0.10	-0.23	0.37	0.708	0.66	0.55	0.83
	1990-2001	ABSA-specific	14.1	7.4	24.3	0.001	0.41	-0.08	0.63	0.054	0.65	0.50	0.76
	1990-2001	Site-wide	16.7	6.5	31.6	<0.001	0.35	-0.16	0.61	0.198	0.77	0.58	1.02
SMALLMOUTH BASS	1983-2001	ABSA-specific	15.4	11.3	21.2	<0.001	0.35	-0.25	0.67	0.358	0.42	0.33	0.61
	1983-2001	Site-wide	15.4	11.1	21.2	<0.001	0.35	-0.25	0.67	0.374	0.41	0.33	0.59
	1990-2001	ABSA-specific	10.7	-0.5	25.1	0.031	0.49	0.24	2.52	0.014	0.43	0.33	0.64
	1990-2001	Site-wide	10.7	-0.5	25.2	0.031	0.48	0.21	2.36	0.022	0.43	0.33	0.63

Note: See footnotes on page 4

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA[2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
NEW RICHMOND													
CARP	1990-2001	ABSA-specific	10.5	0.7	25.4	0.021	0.48	-0.12	1.97	0.074	0.72	0.56	0.84
	1990-2001	Site-wide	21.6	7.1	55.8	0.001	0.24	0.12	0.52	0.026	0.76	0.58	0.90
SMALLMOUTH BASS	1990-2001	ABSA-specific	-1.7	-6.3	3.2	0.744	-1.00	-1.00	1.43	0.624	0.71	0.43	0.93
	1990-2001	Site-wide	-1.6	-6.3	3.2	0.744	-1.00	-1.00	1.71	0.376	0.71	0.43	0.93
SAUGATUCK													
CARP	1983-2001	ABSA-specific	7.5	4.0	10.1	<0.001	0.72	-0.37	1.45	0.440	0.62	0.47	0.76
	1983-2001	Site-wide	4.5	0.7	8.0	0.013	-0.54	-1.00	3.85	0.790	0.63	0.47	0.79
	1990-2001	ABSA-specific	-11.4	-82.7	23.0	0.715	0.01	0.01	0.01	0.000	0.66	0.42	0.74
	1990-2001	Site-wide	30.0	-26.4	73.1	0.154	0.01	0.01	0.01	0.000	0.66	0.42	0.74
SMALLMOUTH BASS	1990-2001	ABSA-specific	-29.1	-49.9	-14.0	1	0.01	0.01	0.01	0.000	0.36	0.24	0.40
	1990-2001	Site-wide	-29.2	-48.6	-14.6	1	0.01	0.01	0.01	0.000	0.36	0.24	0.40
FORMER BRYANT MILL POND													
CARP	1983-2001	ABSA-specific	6.7	1.6	10.3	0.01	0.99	0.59	3.29	0.000	0.50	0.37	0.60
	1983-2001	Site-wide	4.7	0.9	8.0	0.01	0.99	0.59	3.33	0.000	0.50	0.37	0.60

Notes:
1) Exponent in the MO differential equation $dC/dt = kC^{(1-\theta)}$
2) Estimated variance of log-normal error distribution.
3) Site-wide adjustment indicates that concentrations were adjusted to site-wide average length and lipid content, and ABSA-specific adjustment indicates that concentrations were adjusted to within ABSA average length and lipid content.
4) One sided test of the null hypothes of no reduction in adjusted concentration over the period of time monitored.
5) One tailed test of the null hypothesis that the decay rate is exponential.

Note: See footnotes on page 4

TABLE 5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB CONCENTRATION HALF TIME (YEARS) IN SMALLMOUTH BASS AND CARP FILLETS

	PCB Half Time (1983-2001)			PCB Half Time (1990-2001)		
Species	Half Time	LCL 95	UCL 95	Half Time	LCL 95	UCL 95
BATTLE CREEK						
CARP	Not Decreasing	28	Not Decreasing	415	9	Not Decreasing
Smallmouth Bass	11	7	24	10	6	23
MORROW POND						
CARP	6	5	8	14	6	Not Decreasing
Smallmouth Bass	6	5	10	8	5	51
DOWNSTREAM OF MORROW DAM						
CARP	6	4	23	6	4	23
Smallmouth Bass	12	5	Not Decreasing	12	5	Not Decreasing
MOSEL AVENUE						
CARP	23	11	Not Decreasing	12	6	68
Smallmouth Bass	Not Decreasing	52	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
PLAINWELL DAM						
CARP	13	9	25	23	9	Not Decreasing
Smallmouth Bass	7	4	32	7	4	29
OTSEGO CITY DAM						
CARP	16	6	Not Decreasing	16	6	Not Decreasing
Smallmouth Bass	8	3	Not Decreasing	8	3	Not Decreasing
OTSEGO DAM						
CARP	Not Decreasing	13	Not Decreasing	Not Decreasing	13	Not Decreasing
Smallmouth Bass	11	6	36	11	6	36

TABLE 5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB CONCENTRATION HALF TIME (YEARS) IN SMALLMOUTH BASS AND CARP FILLETS

Species	PCB Half Time (1983-2001)			PCB Half Time (1990-2001)		
	Half Time	LCL 95	UCL 95	Half Time	LCL 95	UCL 95
TROWBRIDGE DAM						
CARP	10	5	Not Decreasing	10	5	Not Decreasing
Smallmouth Bass	10	6	20	10	6	20
CITY OF ALLEGAN DAM						
CARP	Not Decreasing	21	Not Decreasing	Not Decreasing	21	Not Decreasing
Smallmouth Bass	4	2	12	4	2	12
LAKE ALLEGAN						
CARP	7	6	8	9	5	49
Smallmouth Bass	6	5	7	4	3	9
DOWNSTREAM OF ALLEGAN DAM						
CARP	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
Smallmouth Bass	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
NEW RICHMOND						
CARP	17	5	Not Decreasing	17	5	Not Decreasing
Smallmouth Bass	Not Decreasing	11	Not Decreasing	Not Decreasing	11	Not Decreasing
SAUGATUCK						
CARP	11	8	18	Not Decreasing	2	Not Decreasing
Smallmouth Bass	Not Decreasing	18	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
SAUGATUCK RIVER MOUTH						
CARP	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
MONARCH MILL POND						
CARP	6	5	9	6	5	9

TABLE 5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB CONCENTRATION HALF TIME (YEARS) IN SMALLMOUTH BASS AND CARP FILLETS

Species	PCB Half Time (1983-2001)			PCB Half Time (1990-2001)		
	Half Time	LCL 95	UCL 95	Half Time	LCL 95	UCL 95
FORMER BRYANT MILL POND						
CARP	3	3	4	2	1	3

Figures

FIGURE 1.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SITE MAP

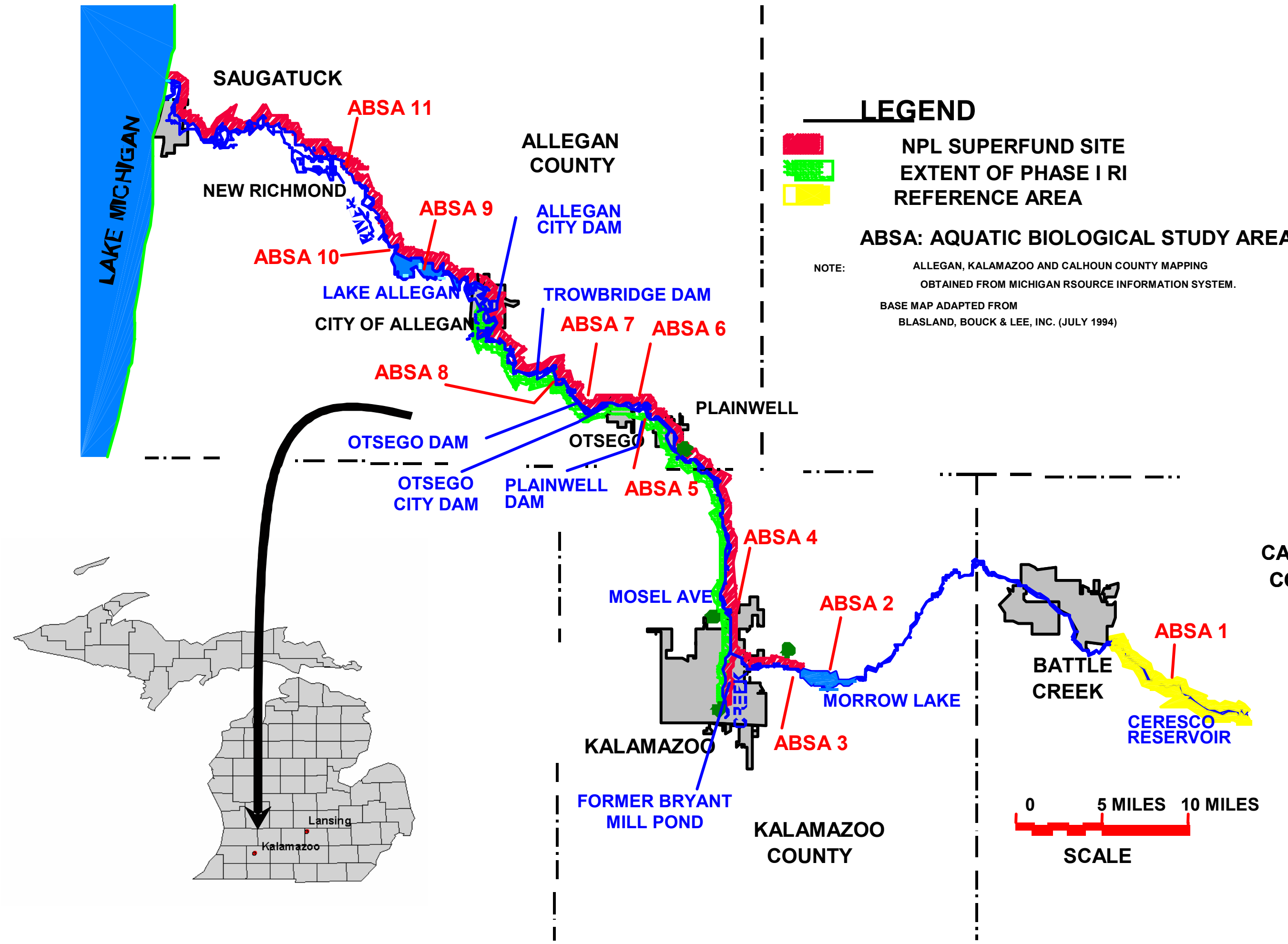


FIGURE 2.

ALLIED PAER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN WET- WEIGHT PCB CONCENTRATION
IN COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

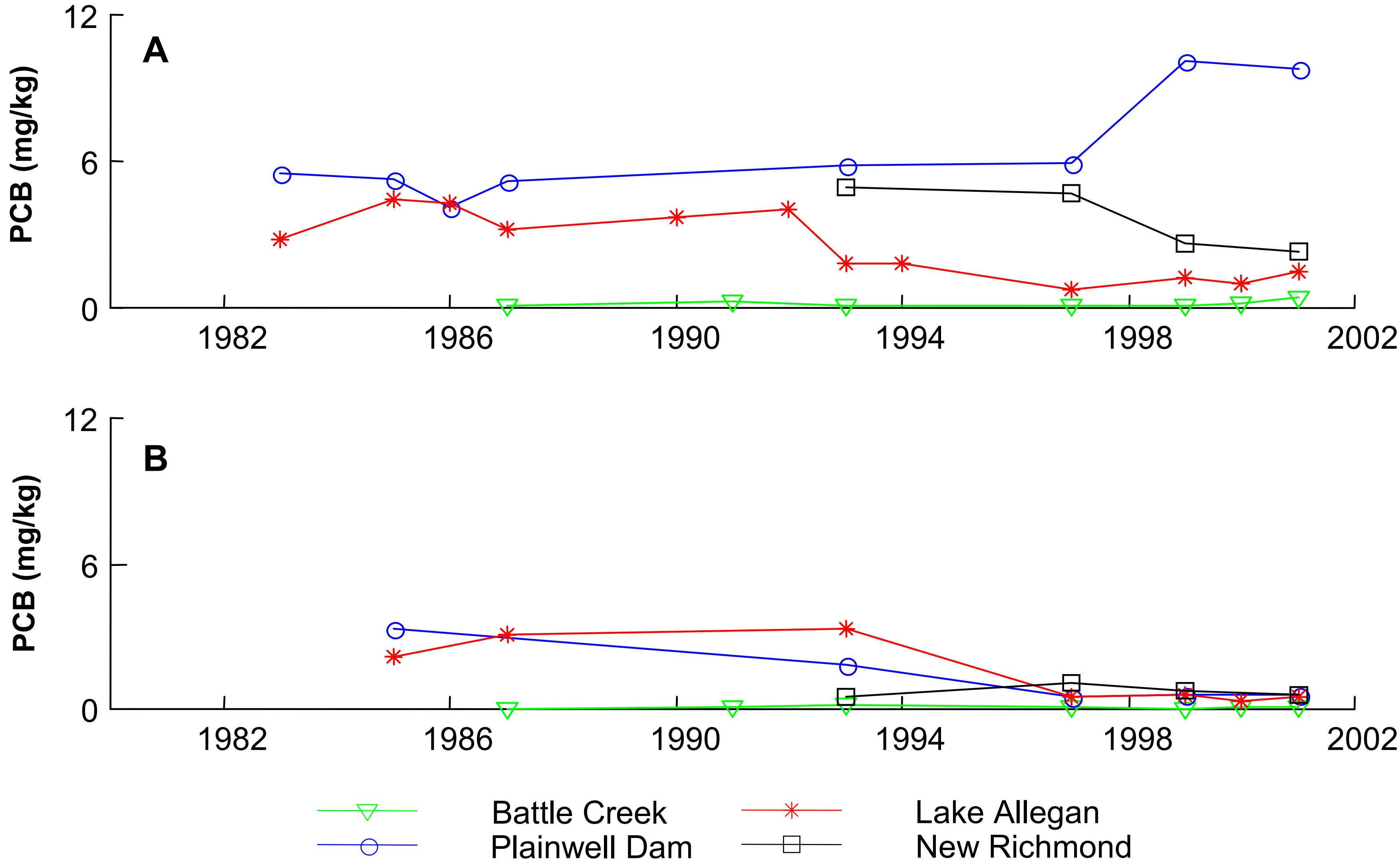


FIGURE 3.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN LIPID CONTENT
IN COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

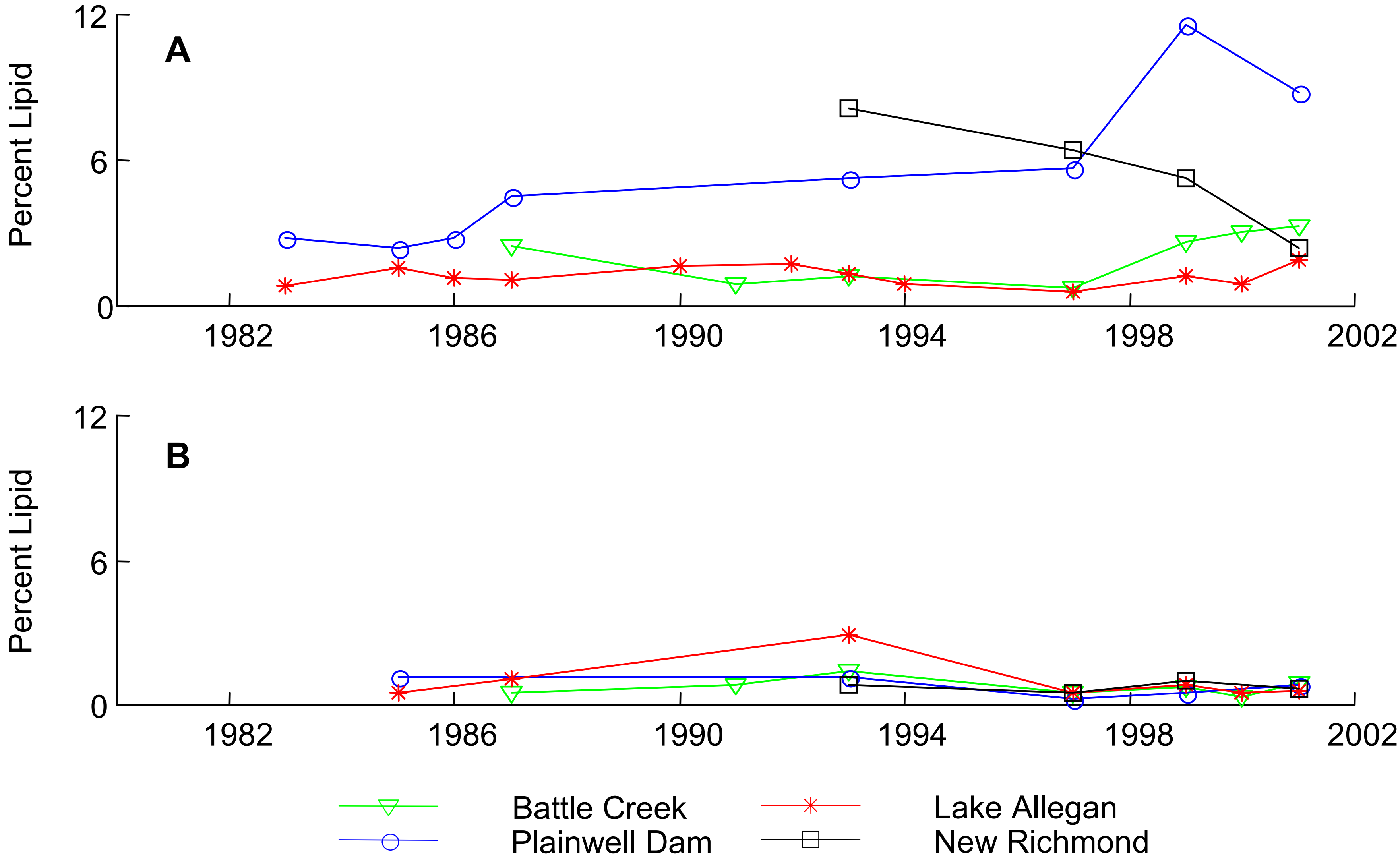


FIGURE 4.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN LENGTH
OF COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

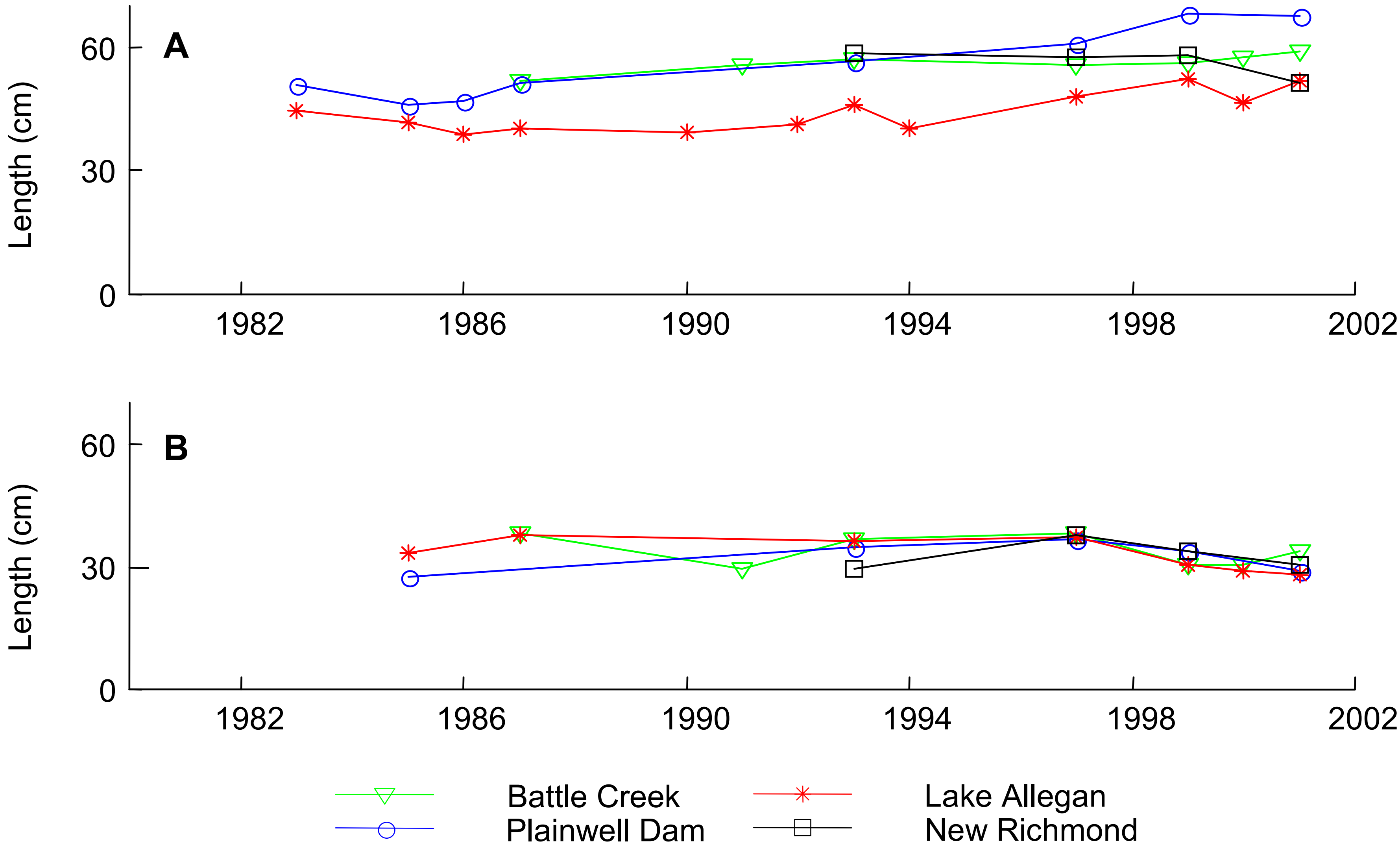


FIGURE 5.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN WEIGHT
OF COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

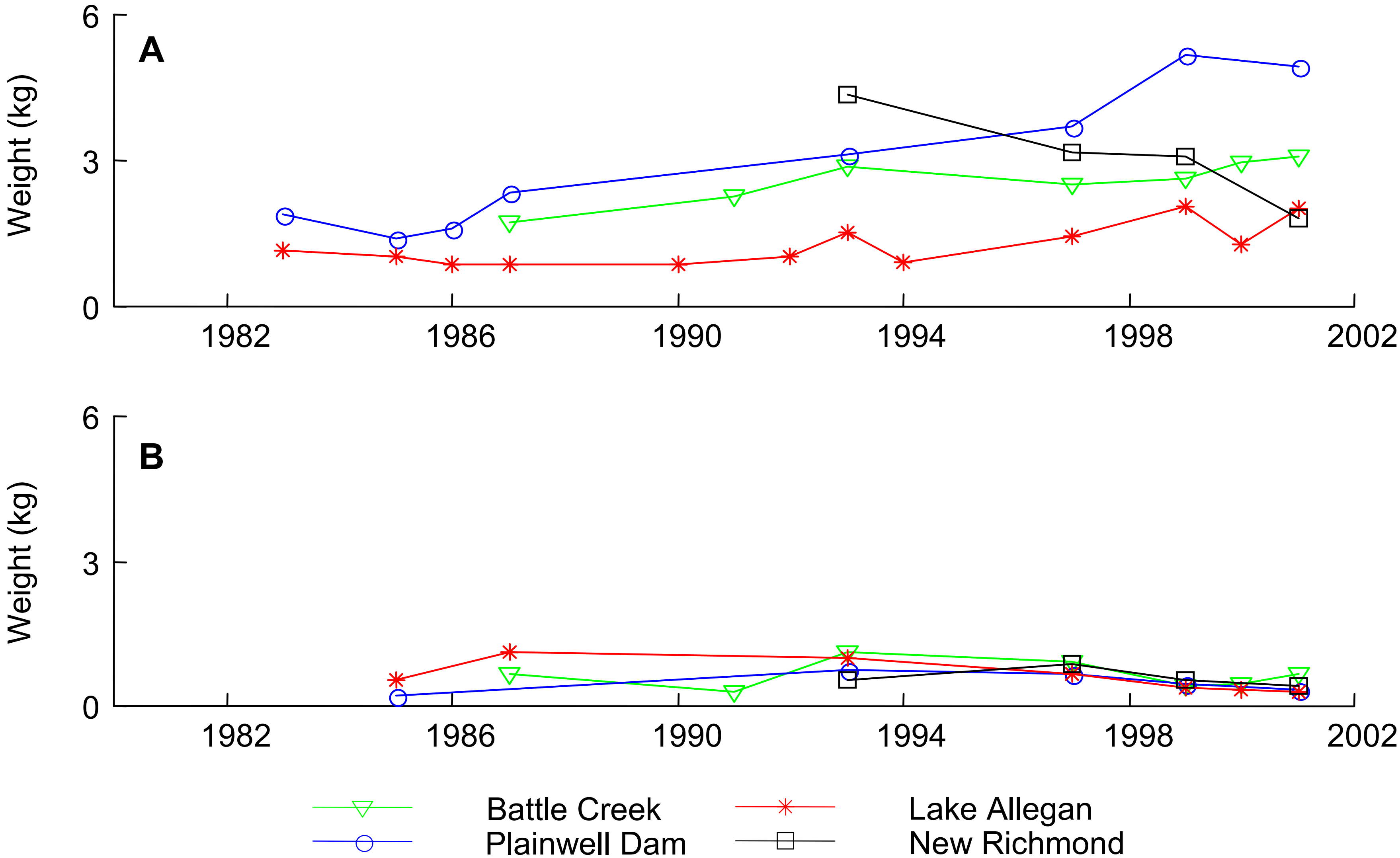


FIGURE 6.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN BODY CONDITION
OF COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

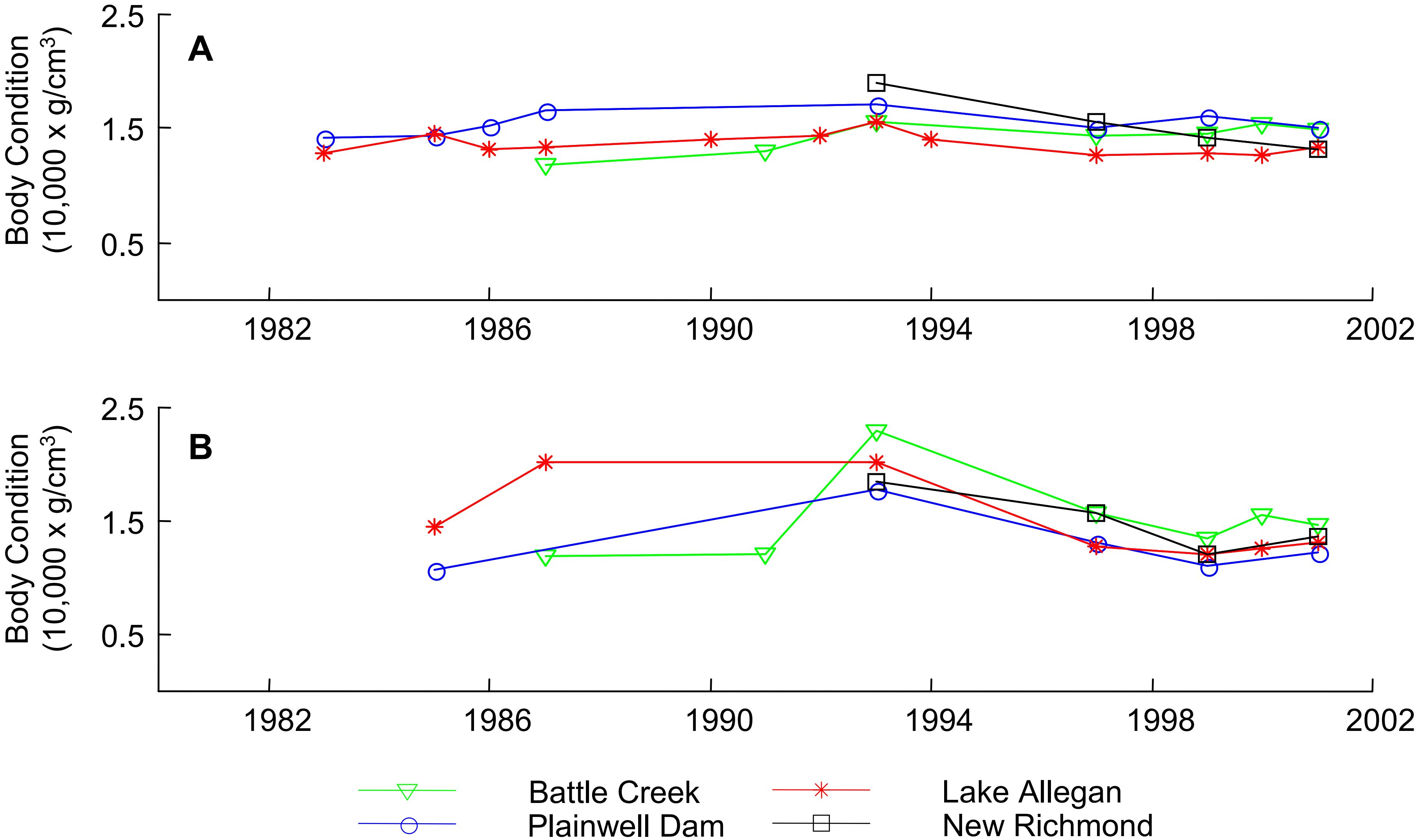


FIGURE 7.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN AVERAGE LENGTH, LIPID AND WET-WEIGHT PCB
IN CARP FILLETS AT LAKE ALLEGAN

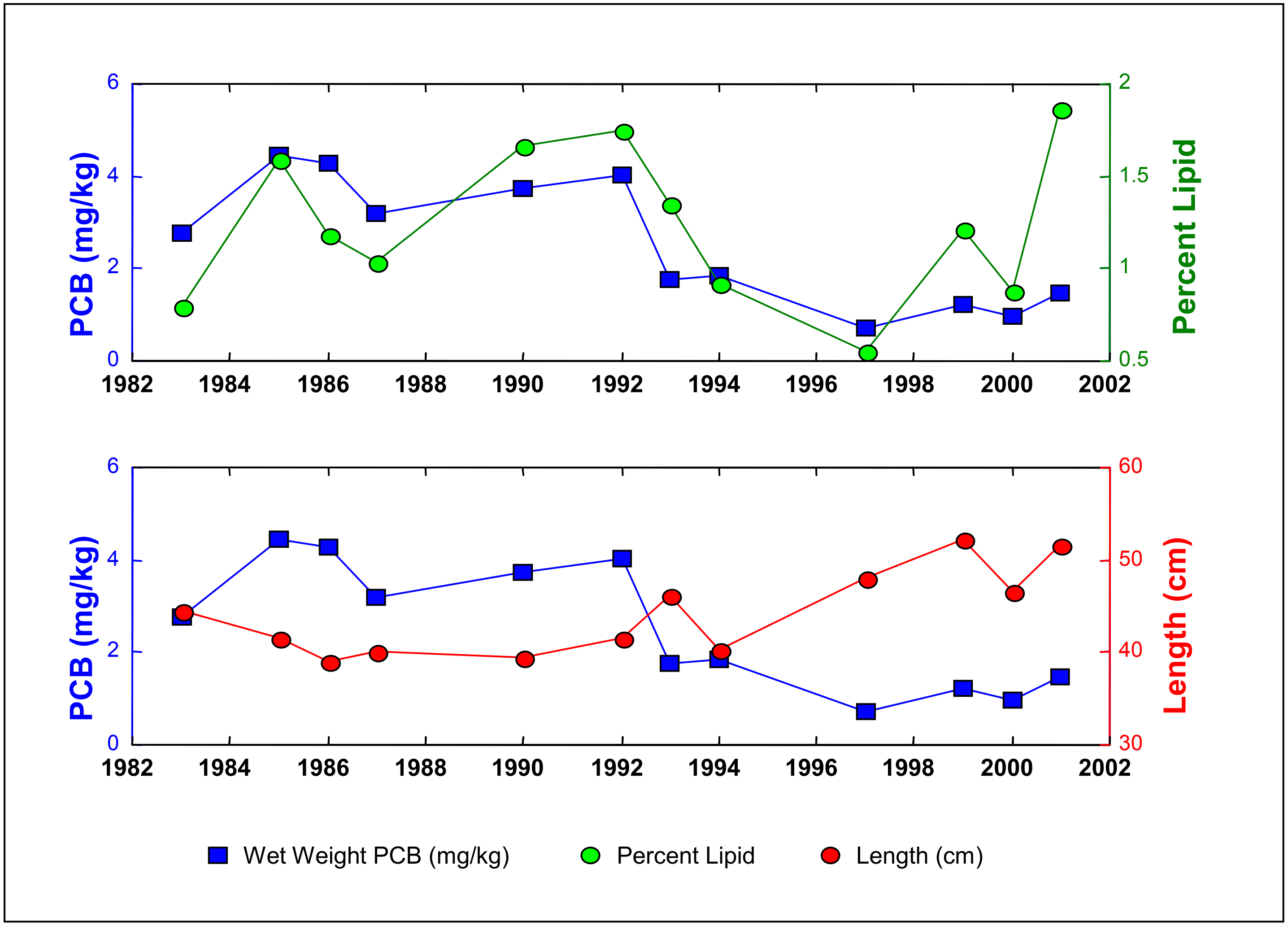


FIGURE 8.

ALLIED PAER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN ADJUSTED PCB CONCENTRATION
IN COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

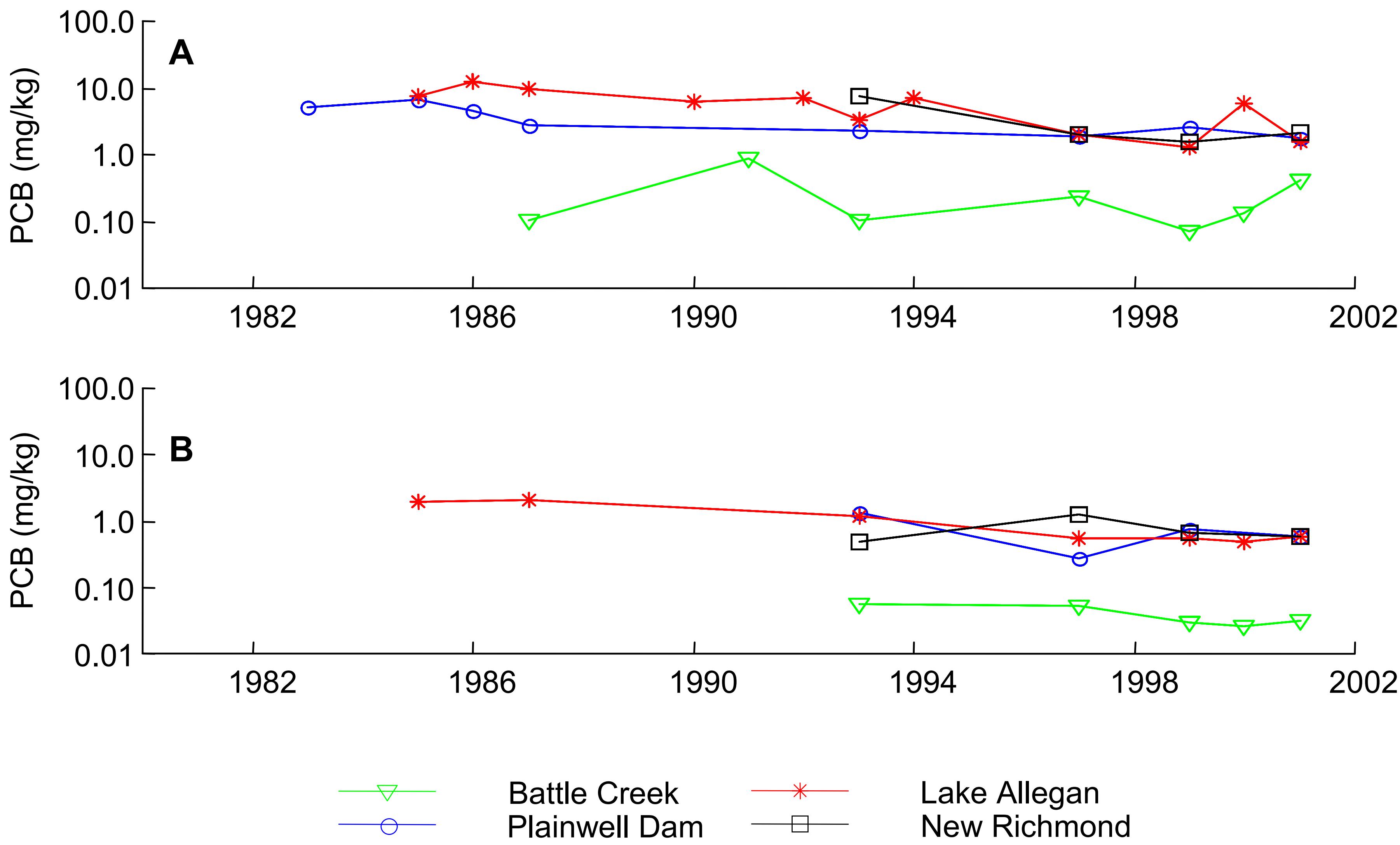


FIGURE 9.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED (SITE-WIDE) PCB CONCENTRATION
IN COMMON CARP AND SMALLMOUTH BASS FILLETS IN 2001
INDEX TO EXPOSURE THAT FISH RECEIVE

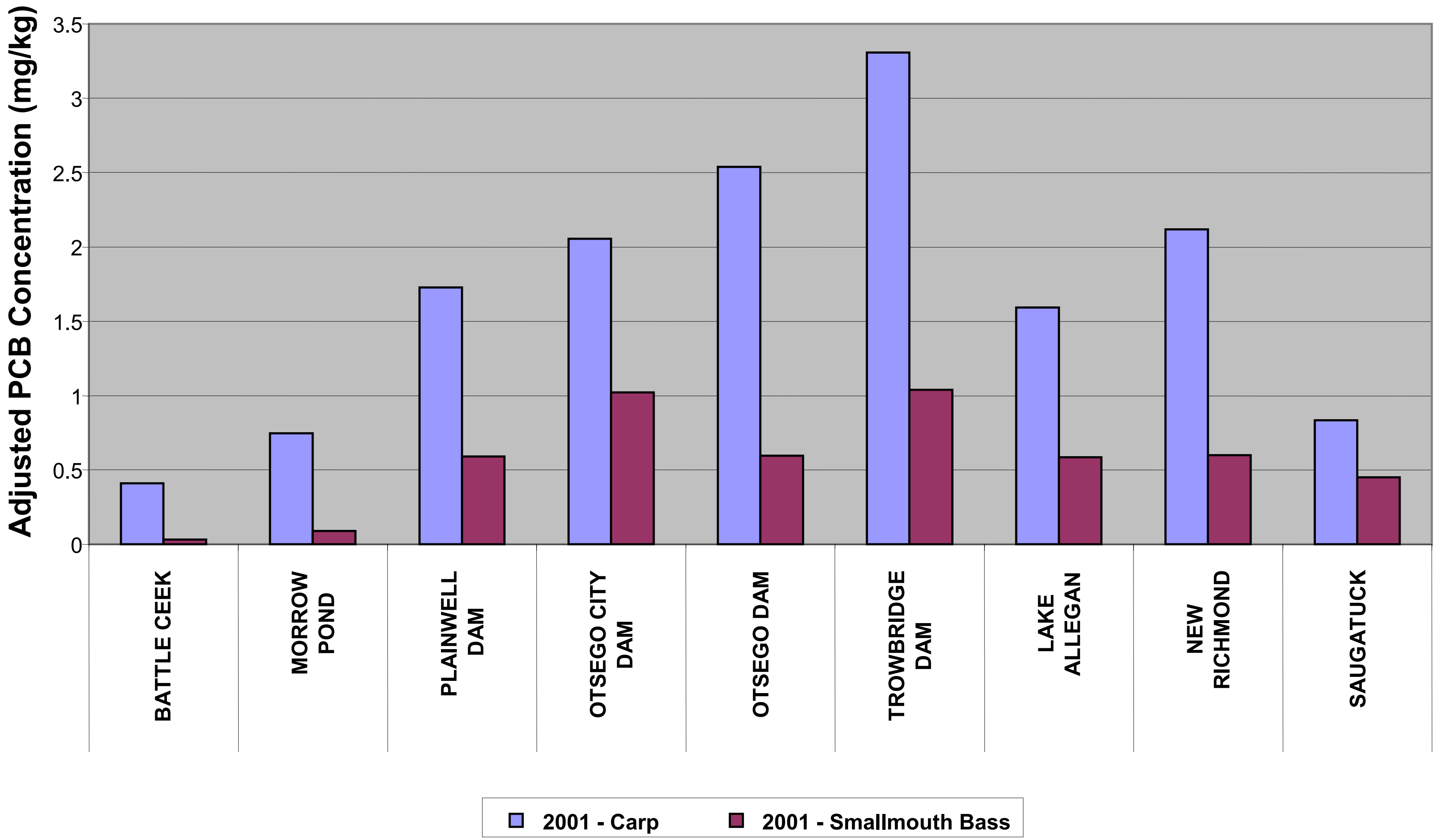


FIGURE 10.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED (ABSA-SPECIFIC) PCB CONCENTRATION
IN COMMON CARP AND SMALLMOUTH BASS FILLETS IN 2001
EXPECTED CHRONIC EXPOSURE FOR FISH CONSUMERS

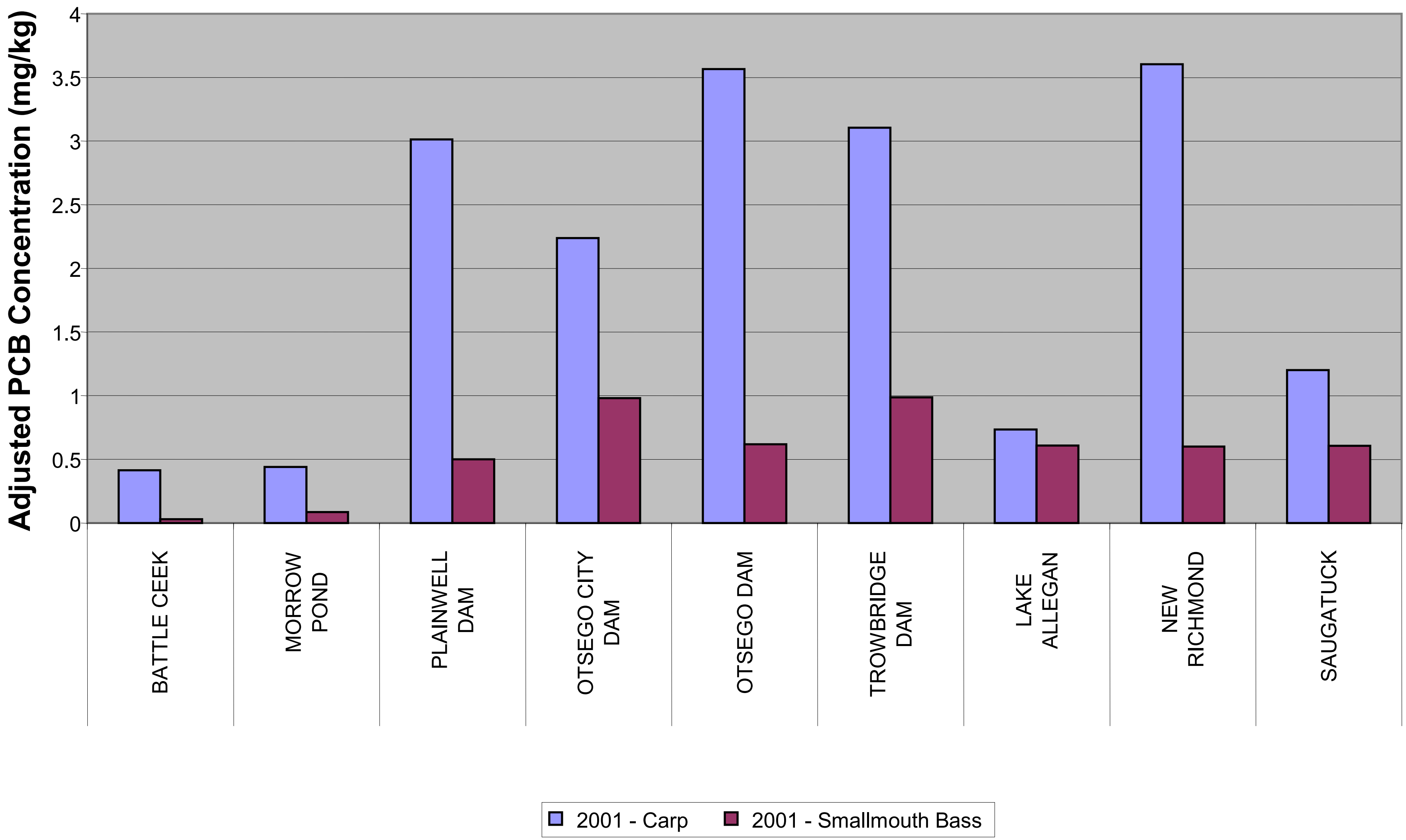
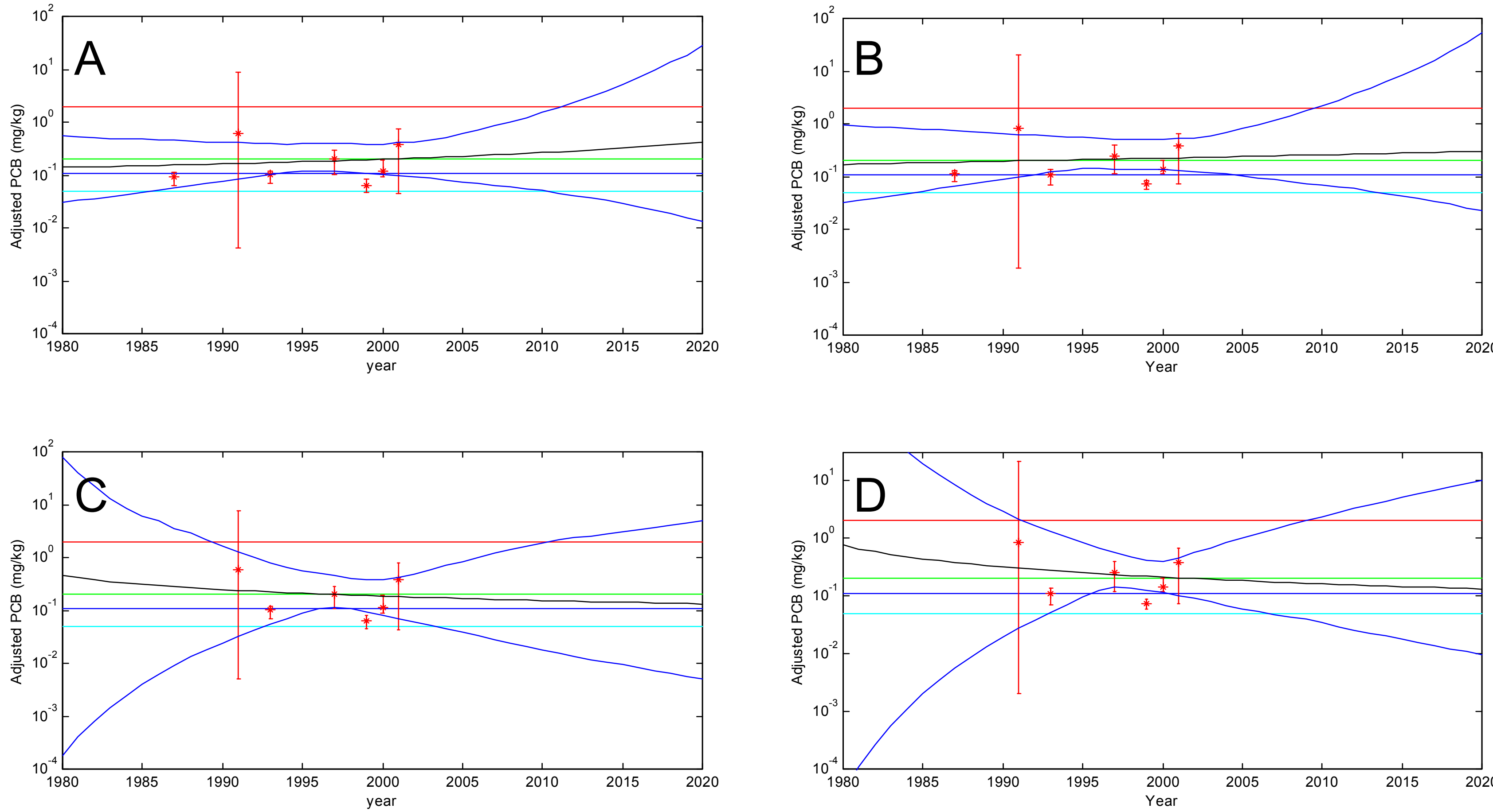


FIGURE 11.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT BATTLE CREEK FOR 1986-2001(PANELS A AND B) AND 1990-2001 (PANELS C AND D).



ABSA-specific Adjusted Data

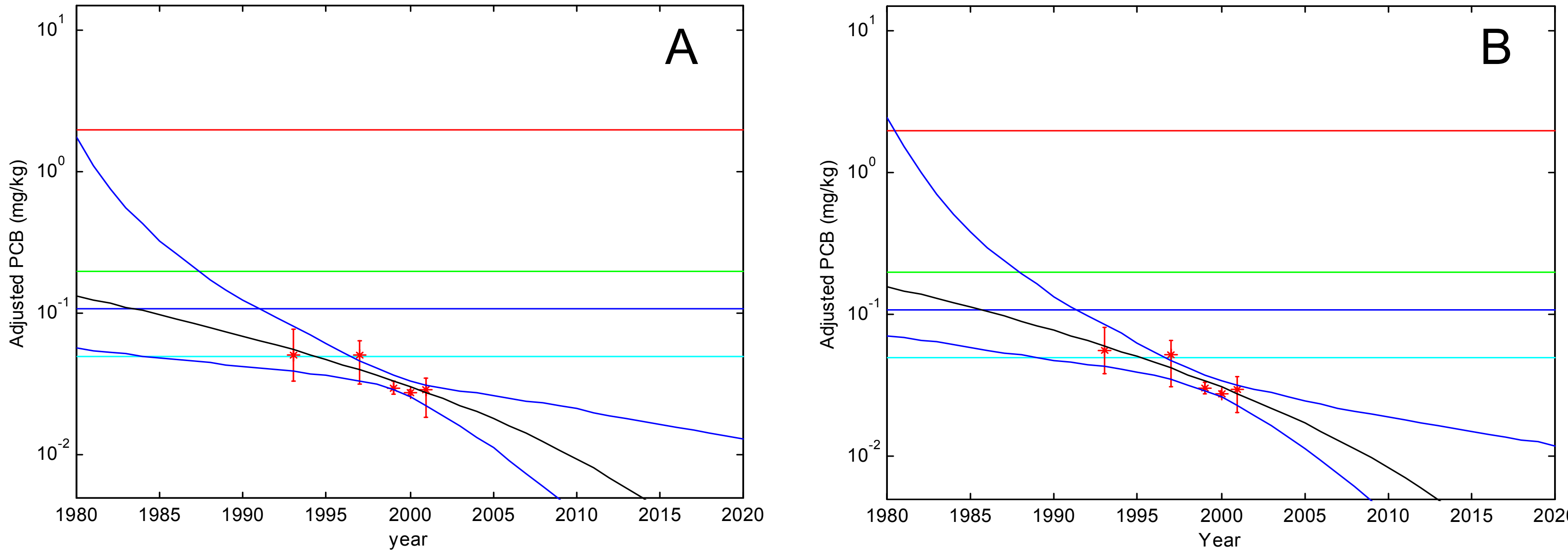
Site-wide Adjusted Data

- 2 mg/kg MDCH General Population No-Consumption
- 0.2 mg/kg MDCH One meal per month (Women and Children)
- 0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)
- 0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 12.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT BATTLE CREEK FOR 1990-2001.



ABSA-specific Adjusted Data

Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 13.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT MORROW POND FOR 1986-2001(PANELS A AND B) AND 1990-2001 (PANELS C AND D).

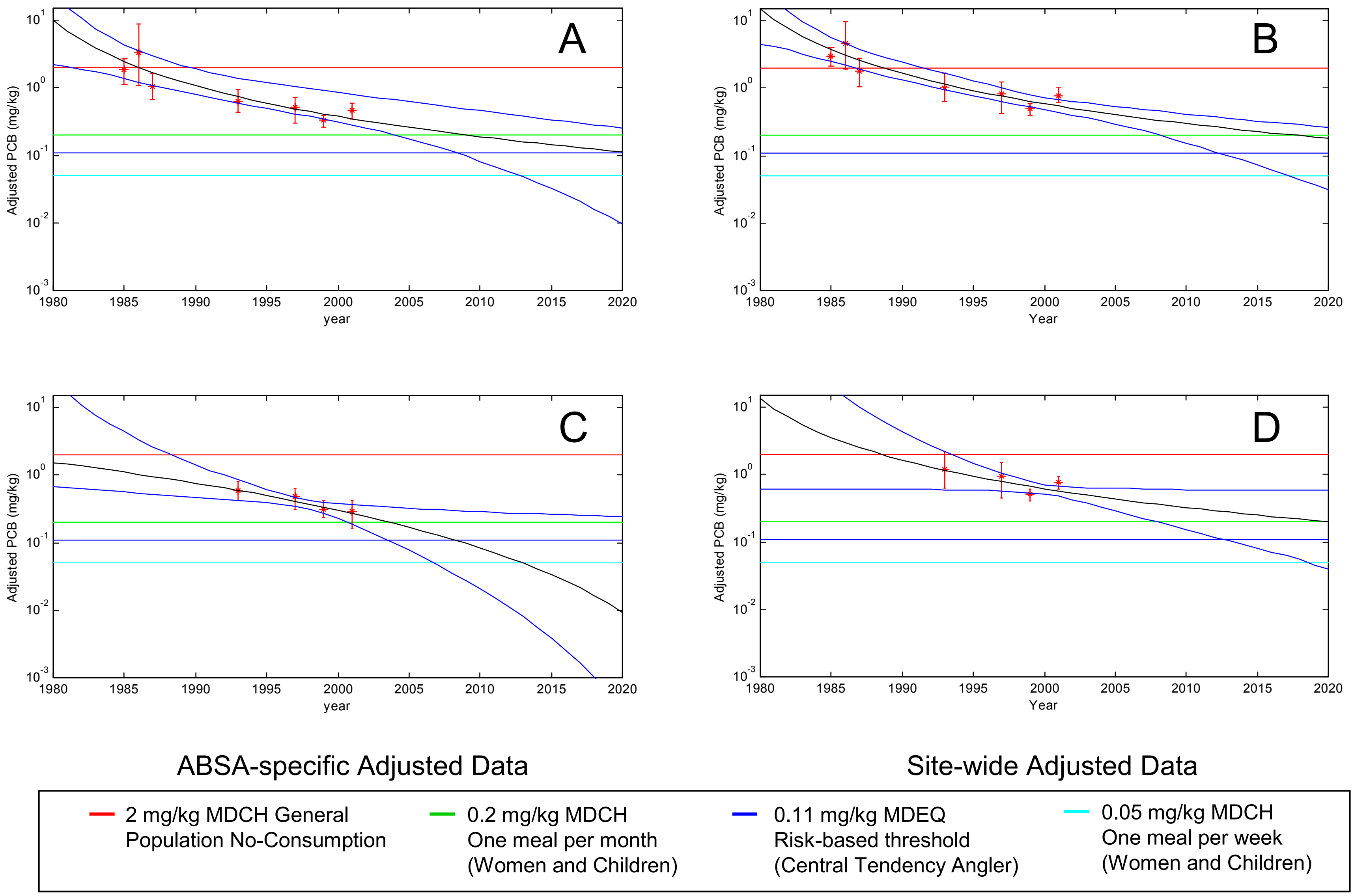
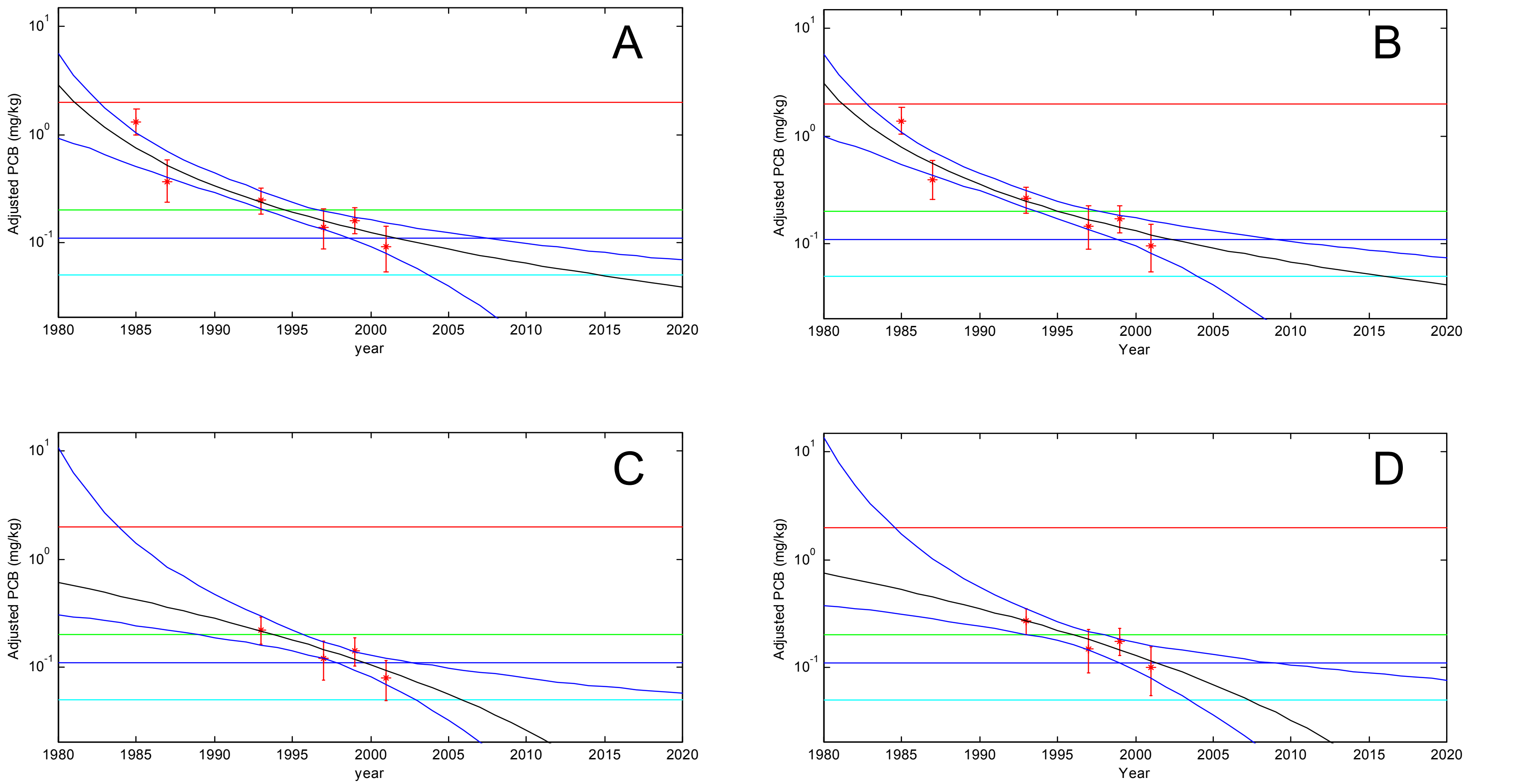


FIGURE 14.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT MORROW POND FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).



ABSA-specific Adjusted Data

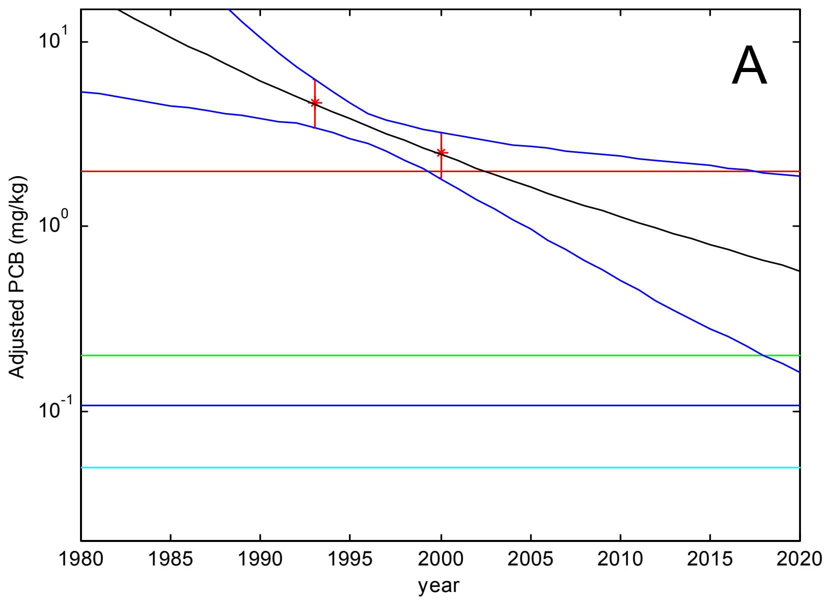
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

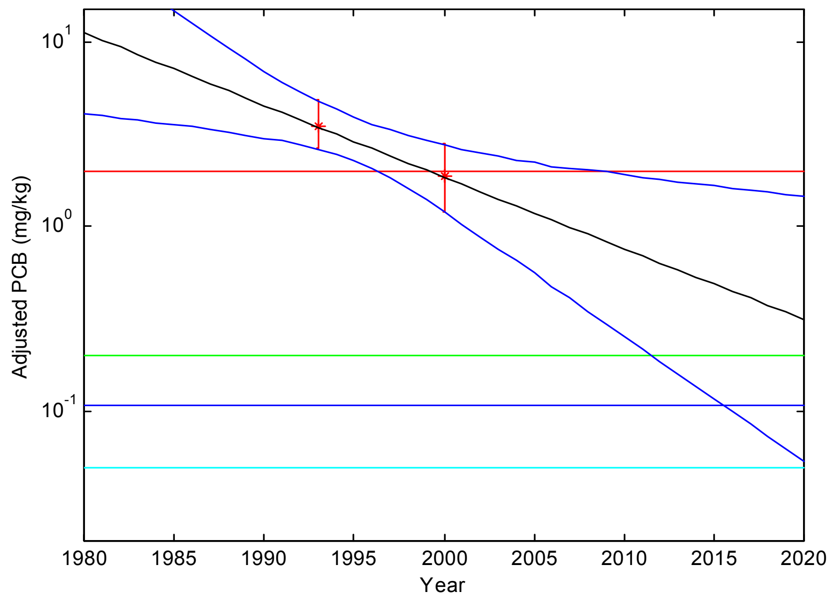
FIGURE 15.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS DOWNSTREAM OF MORROW DAM FOR 1990-2001.



ABSA-specific Adjusted Data



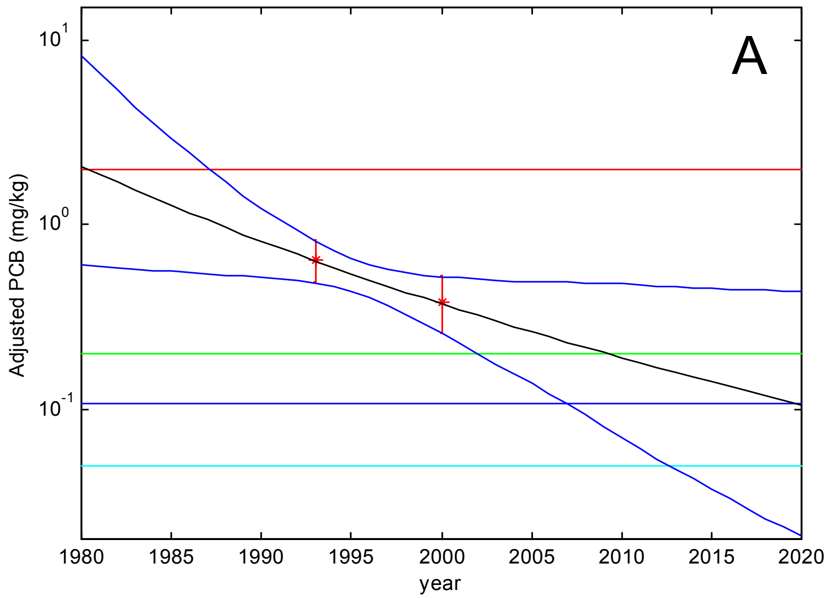
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

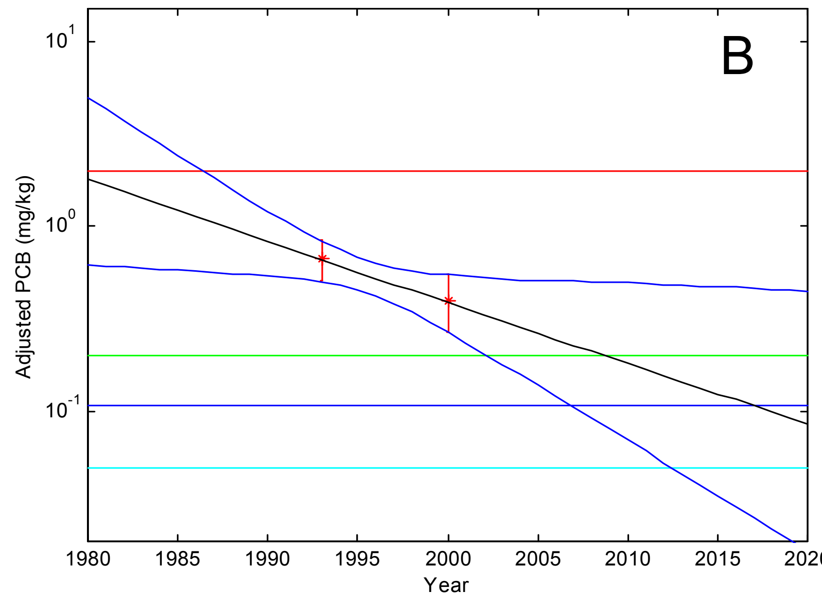
FIGURE 16.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS DOWNSTREAM OF MORROW DAM FOR 1990-2001.



ABSA-specific Adjusted Data



Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 17.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT MOSEL AVENUE FOR 1983-2001(PANELS A AND B) AND 1990-2001 (PANELS C AND D).

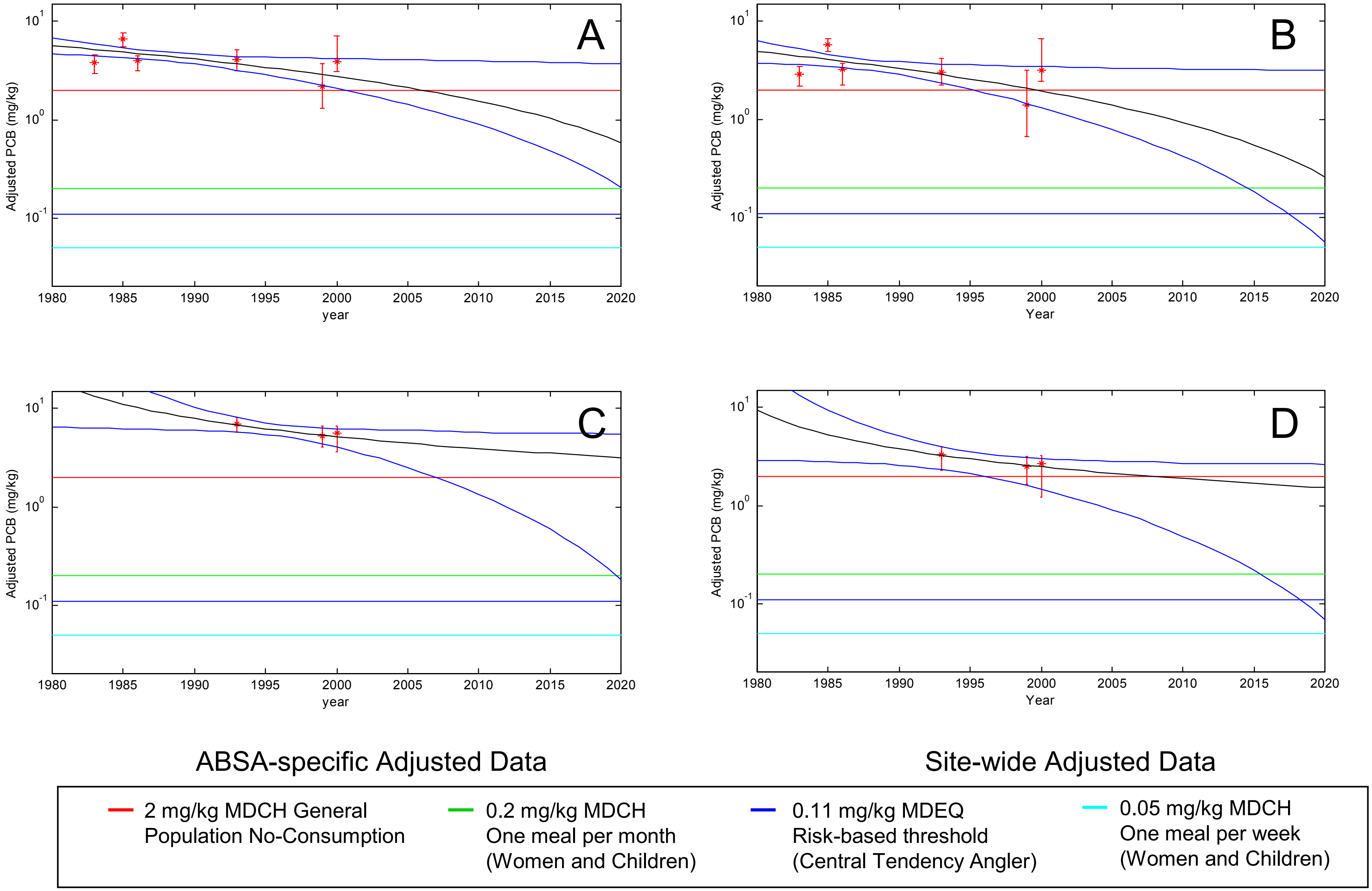
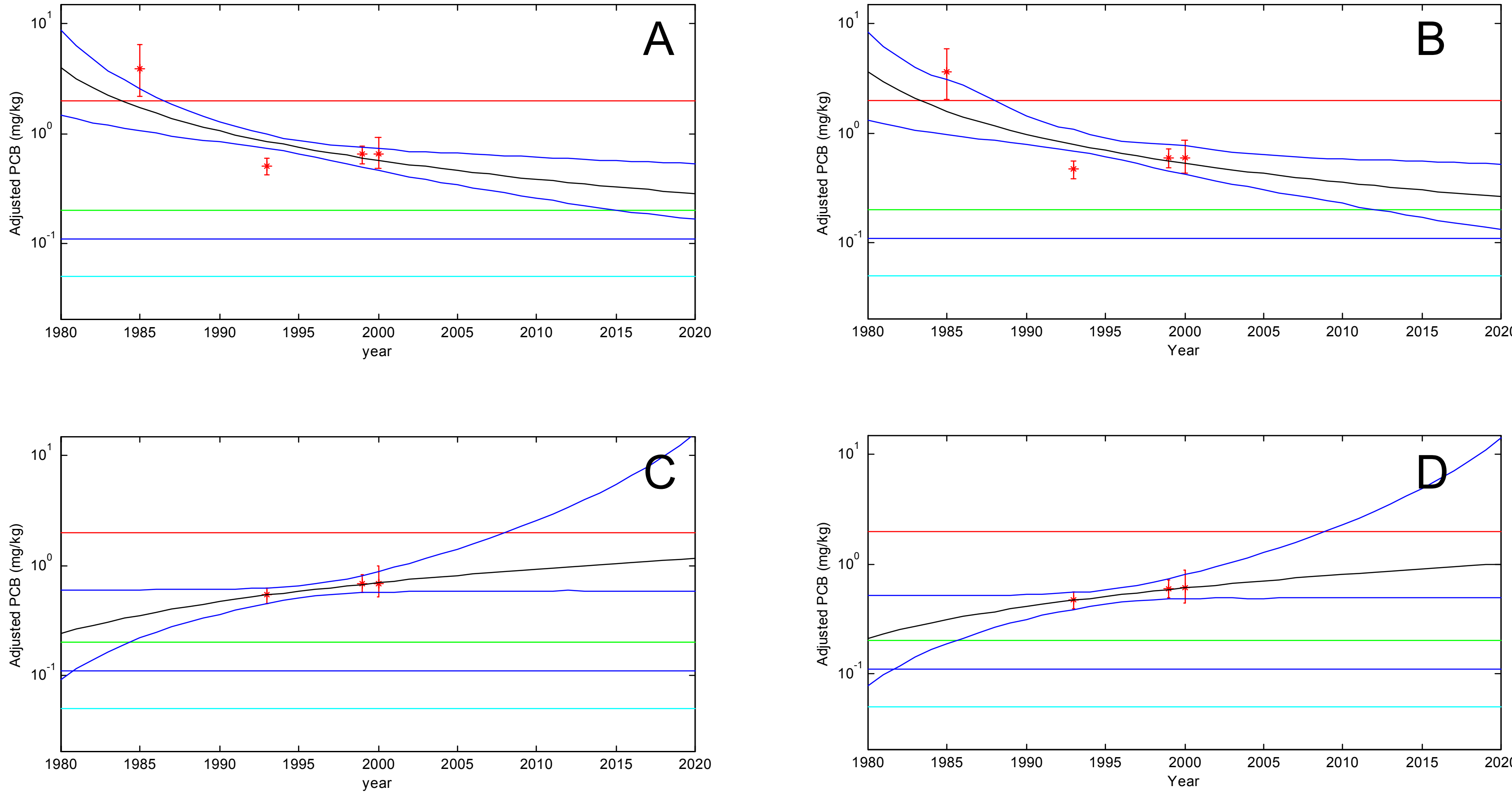


FIGURE 18.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT MOSEL AVENUE FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).



ABSA-specific Adjusted Data

Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 19.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT PLAINWELL IMPOUNDMENT FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).

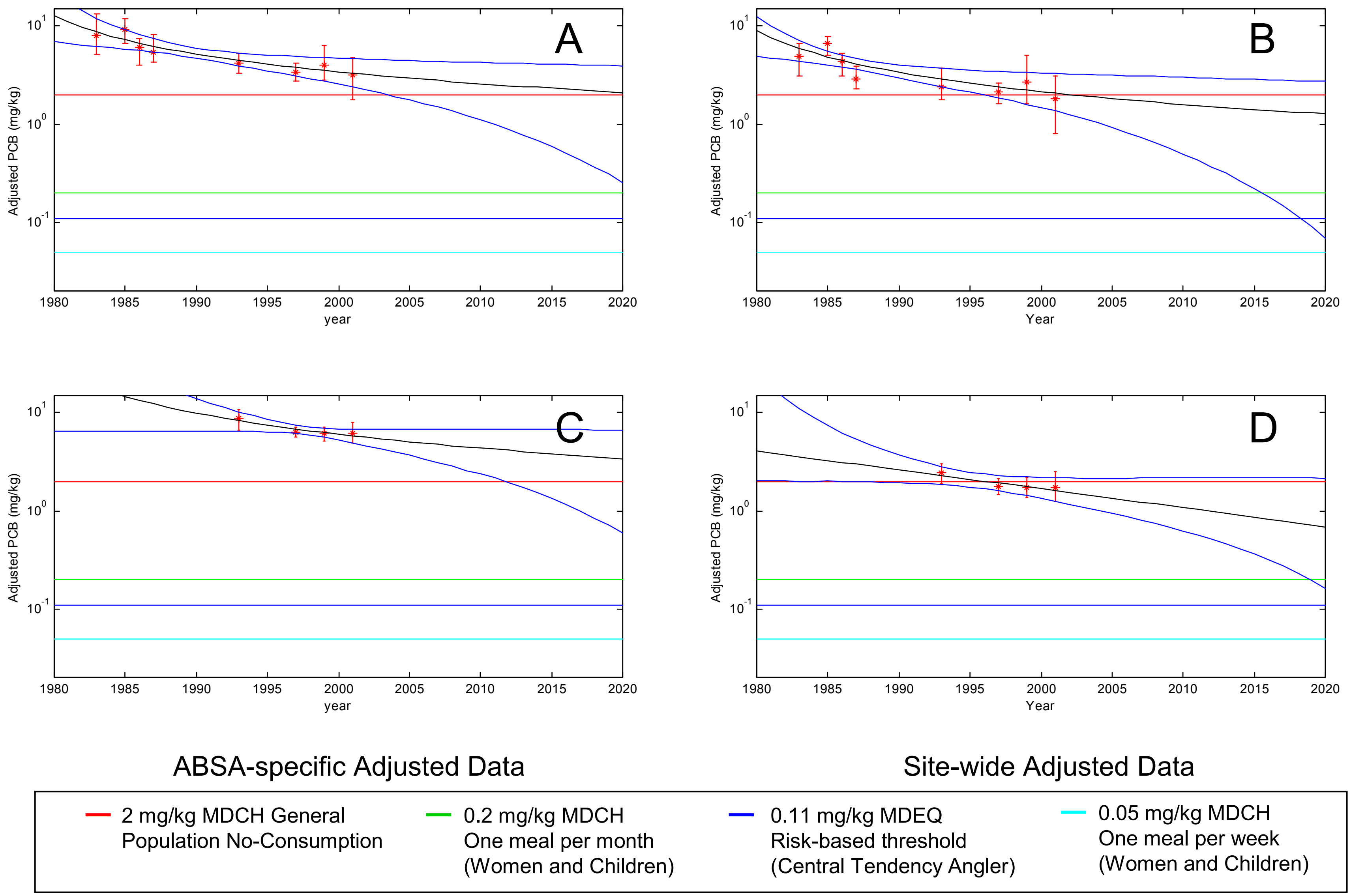
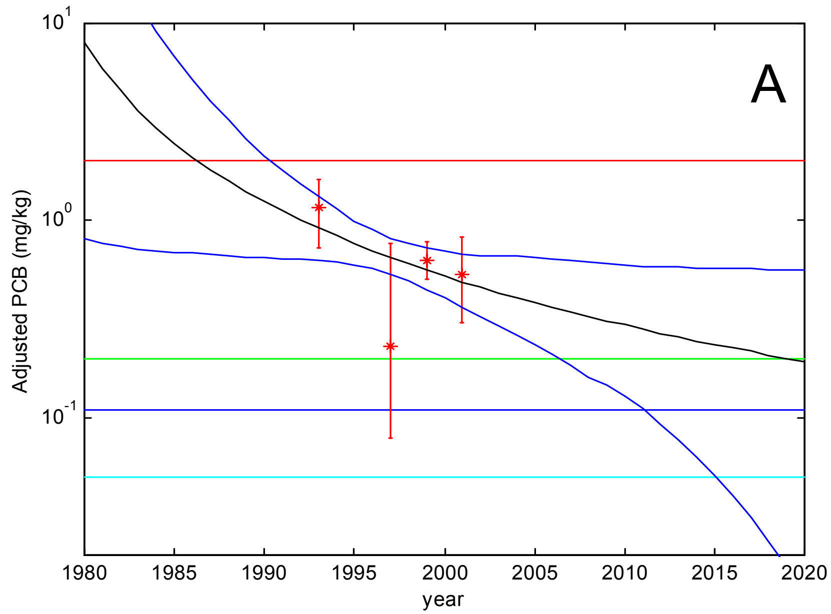


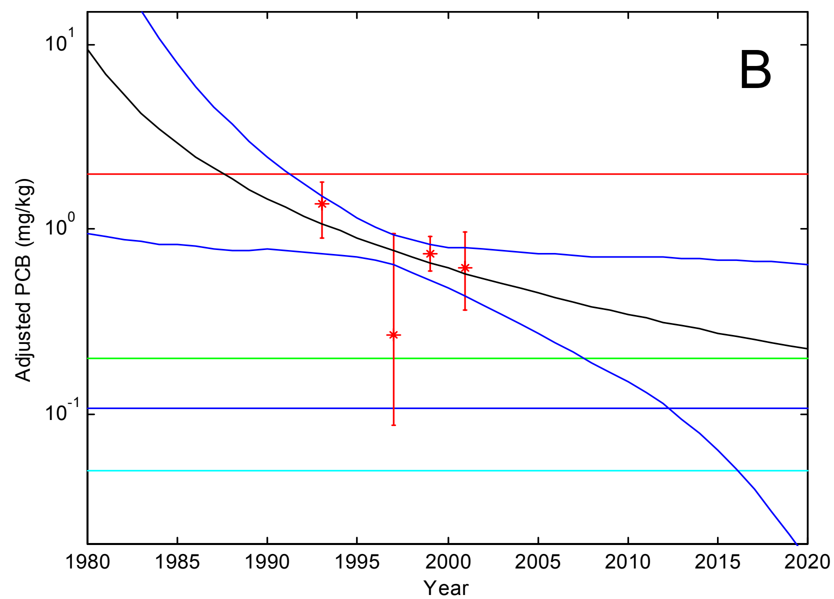
FIGURE 20.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT PLAINWELL IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data



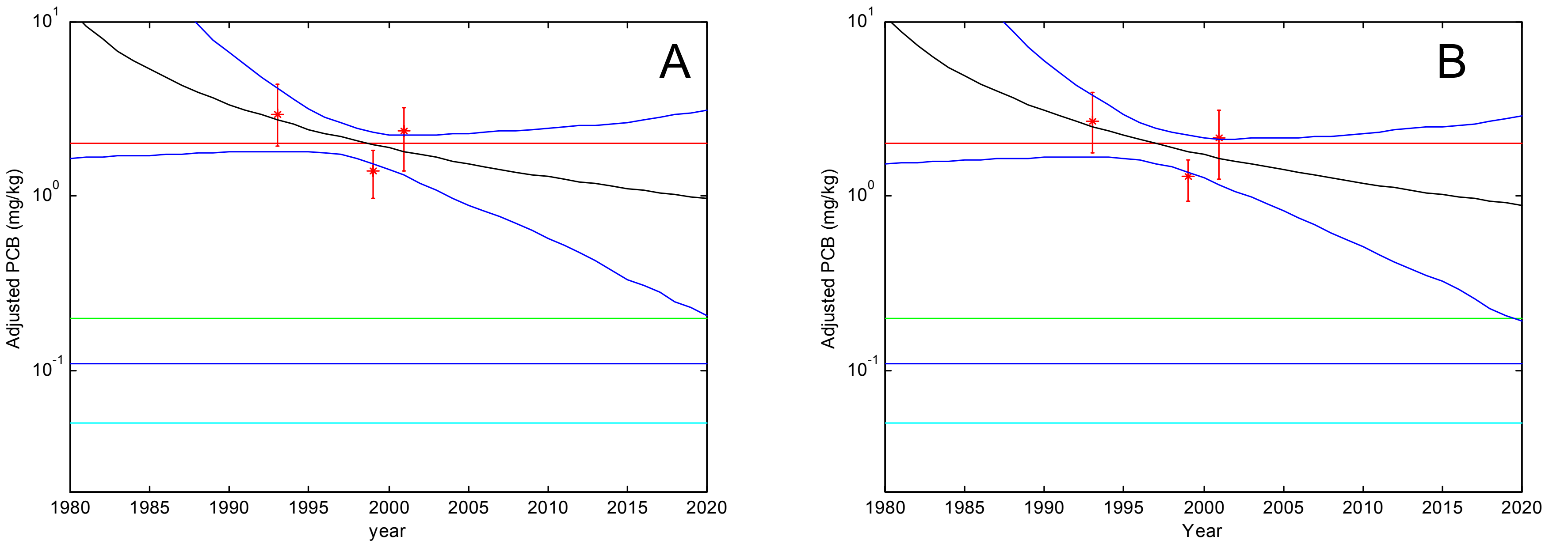
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 21.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT OTSEGO CITY IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

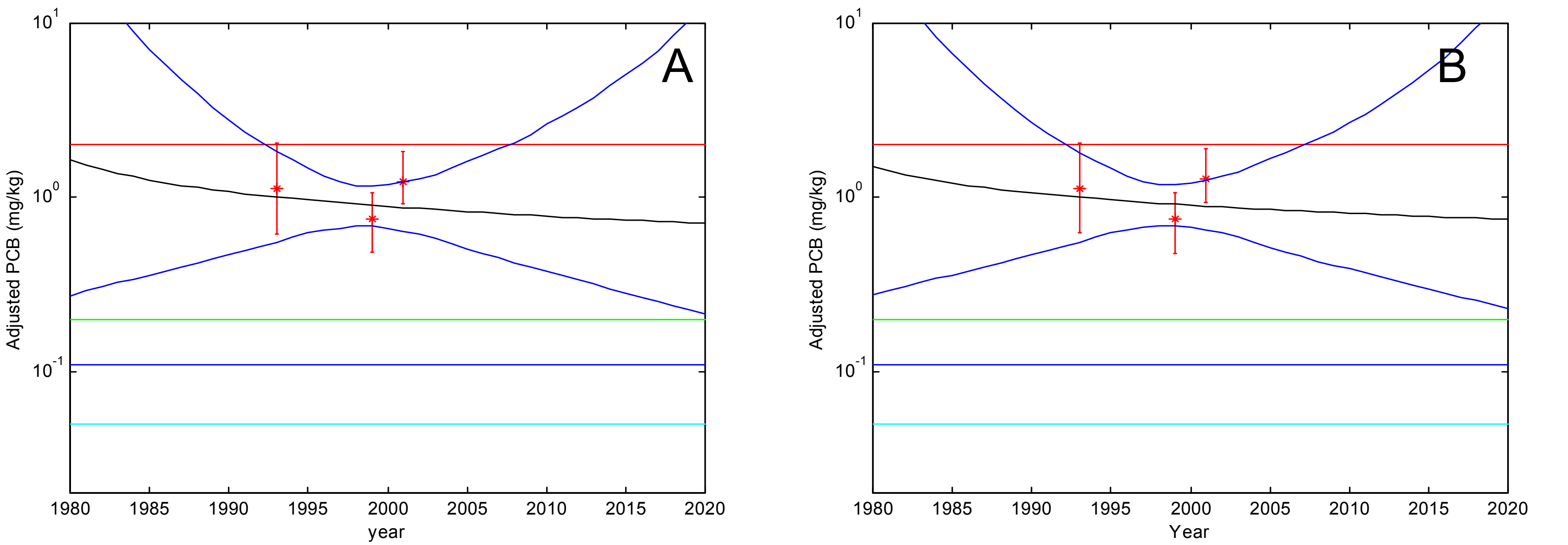
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 22.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT OTSEGO CITY IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

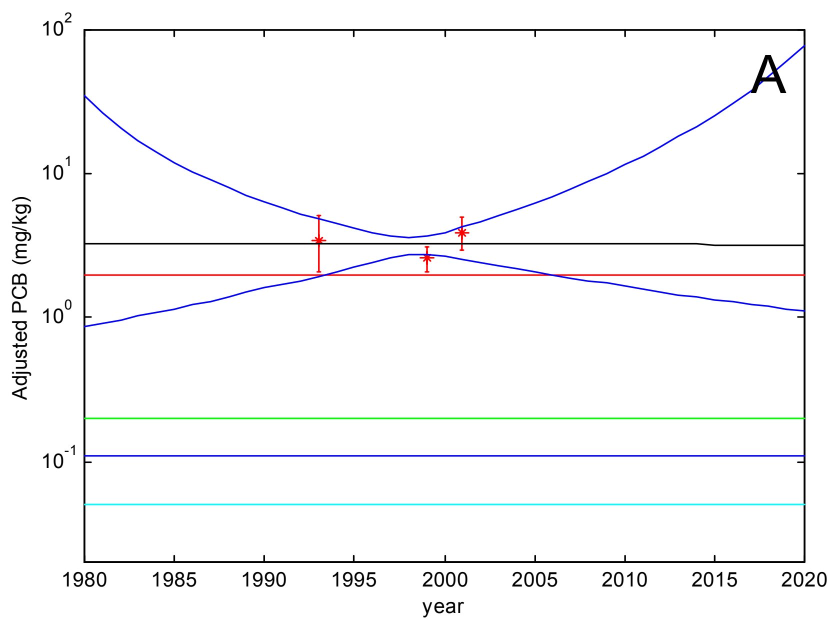
Site-wide Adjusted Data

- 2 mg/kg MDCH General Population No-Consumption
- 0.2 mg/kg MDCH One meal per month (Women and Children)
- 0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)
- 0.05 mg/kg MDCH One meal per week (Women and Children)

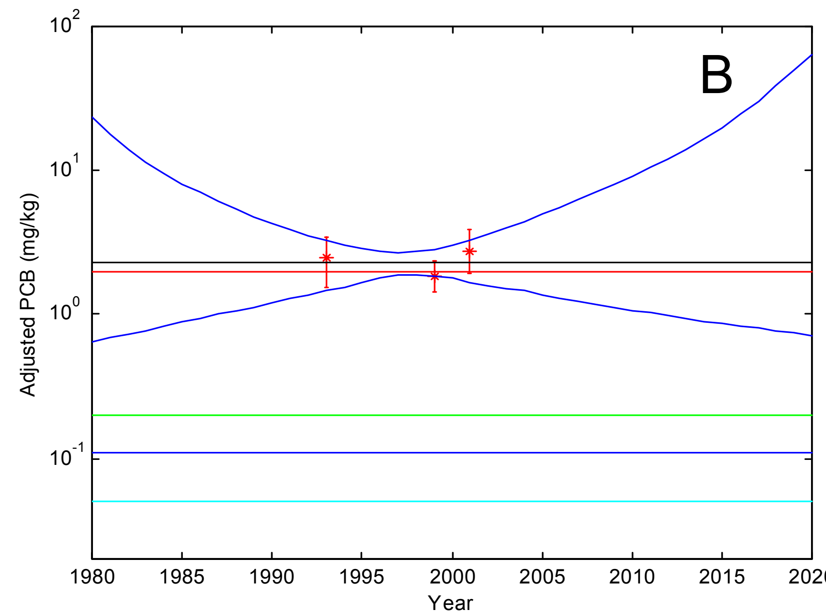
FIGURE 23.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT OTSEGO IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data



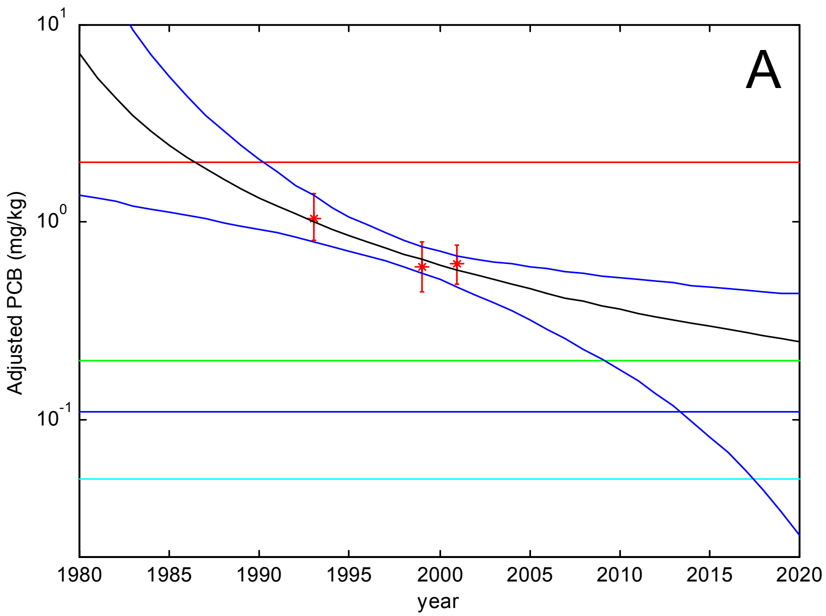
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

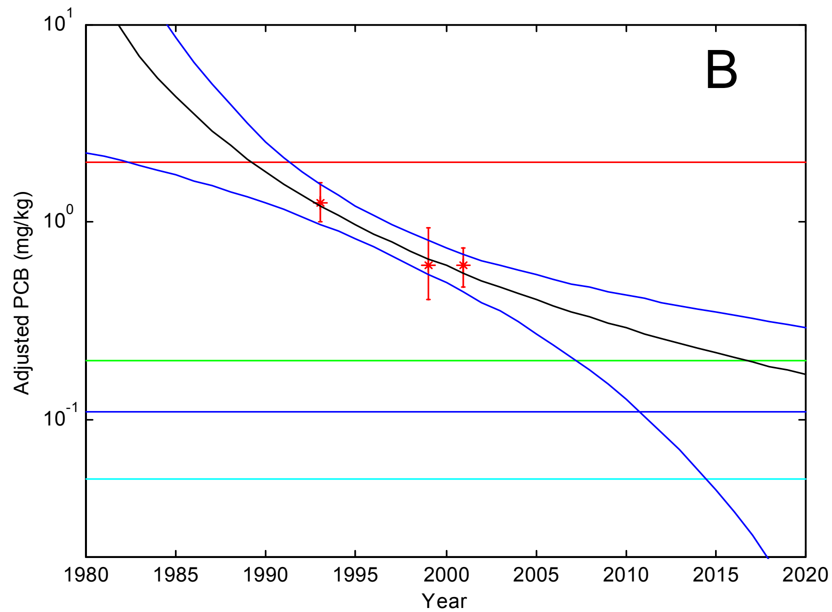
FIGURE 24.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT OTSEGO IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data



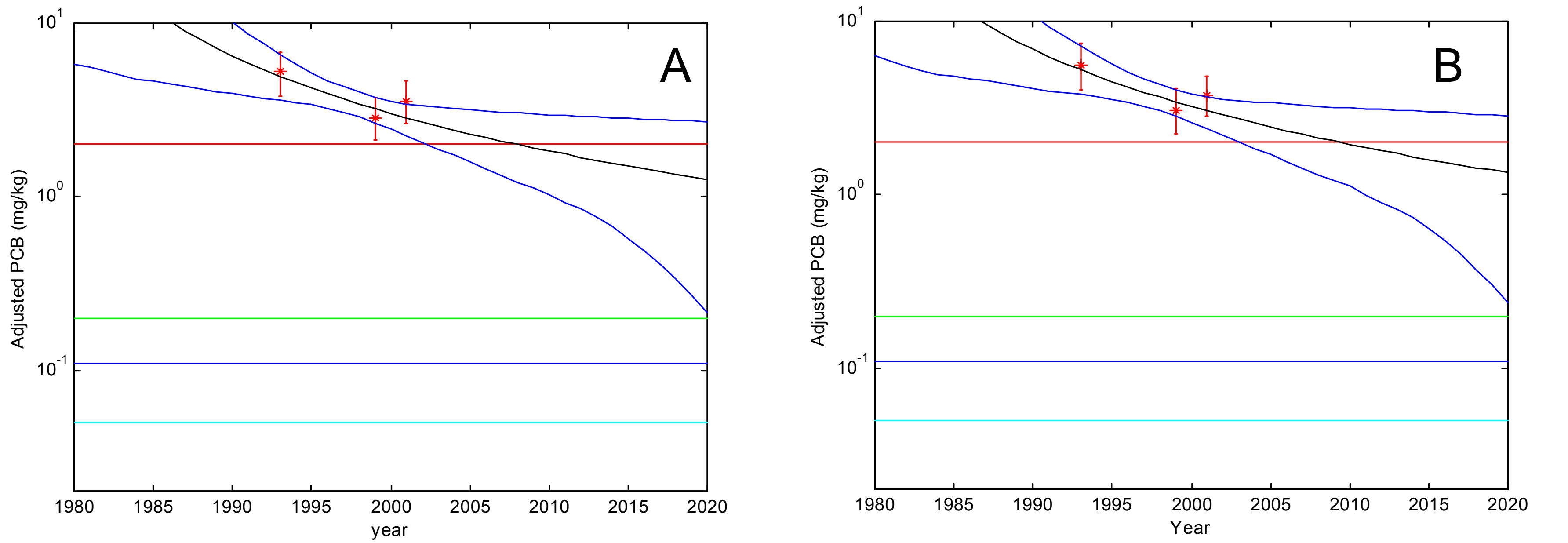
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 25.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT TROWBRIDGE IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption

0.2 mg/kg MDCH One meal per month (Women and Children)

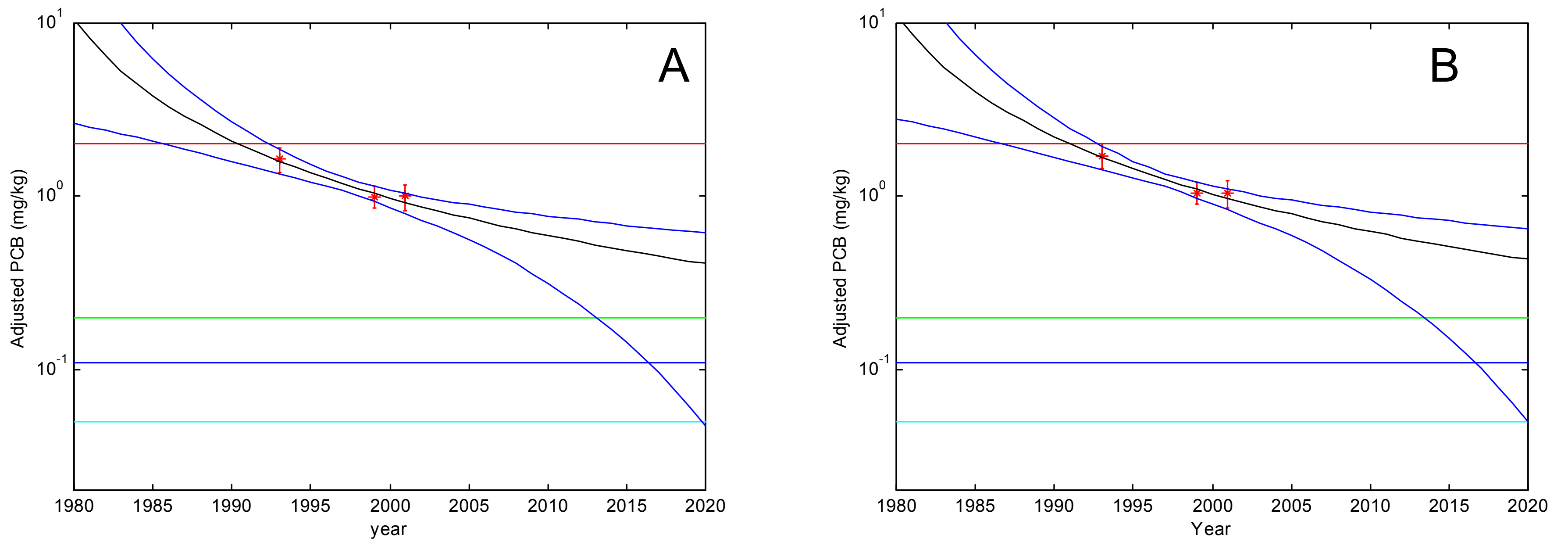
0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)

0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 26.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT TROWBRIDGE IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

Site-wide Adjusted Data

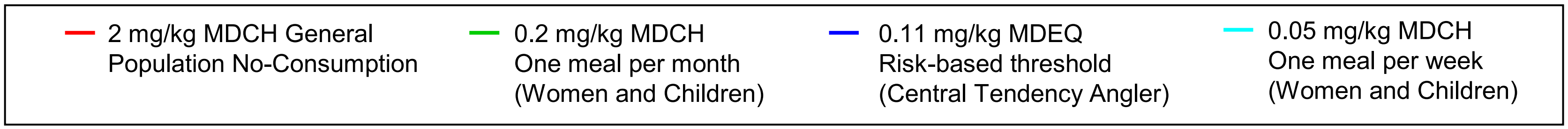


FIGURE 27.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT LAKE ALLEGAN FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).

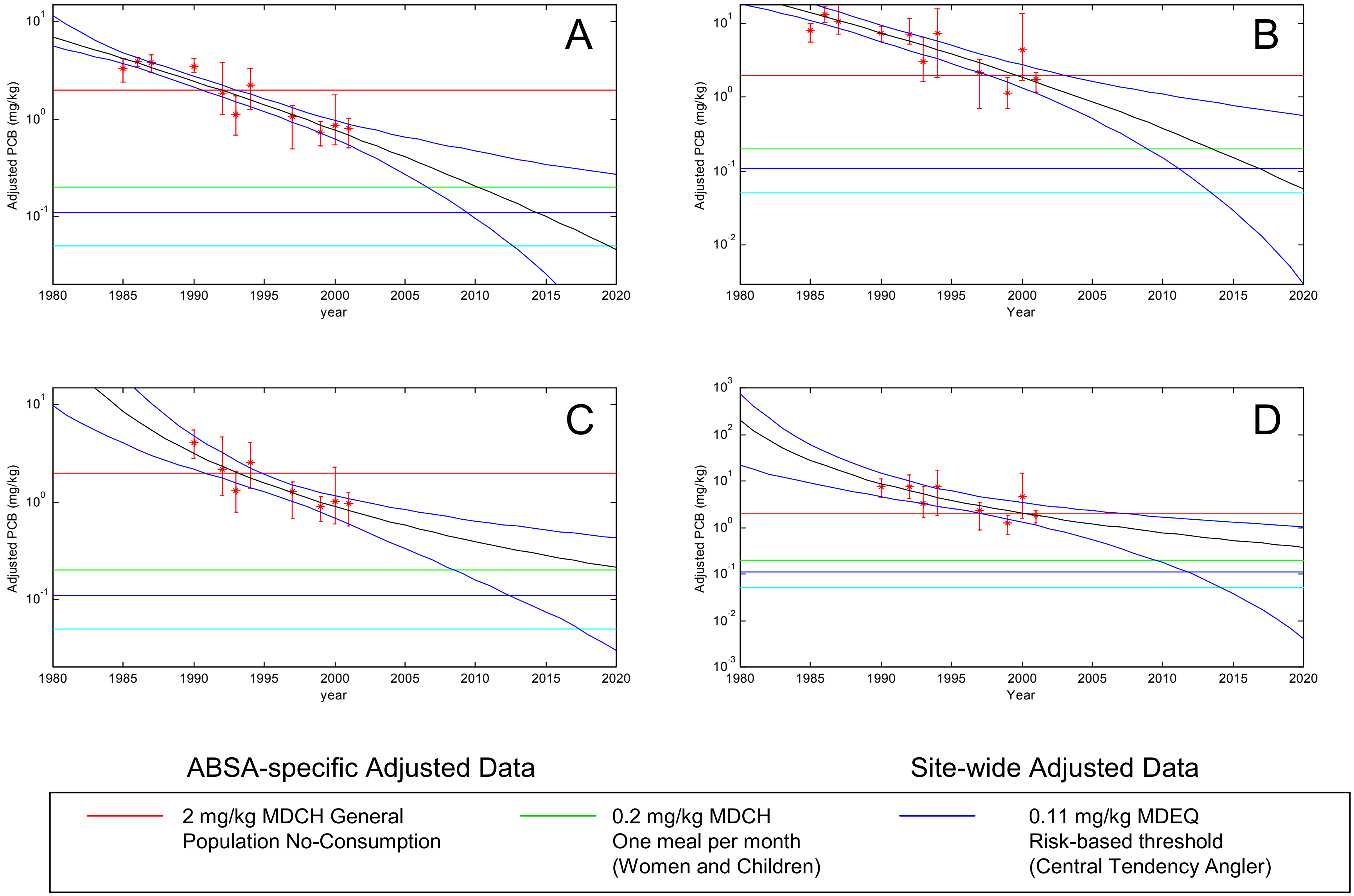
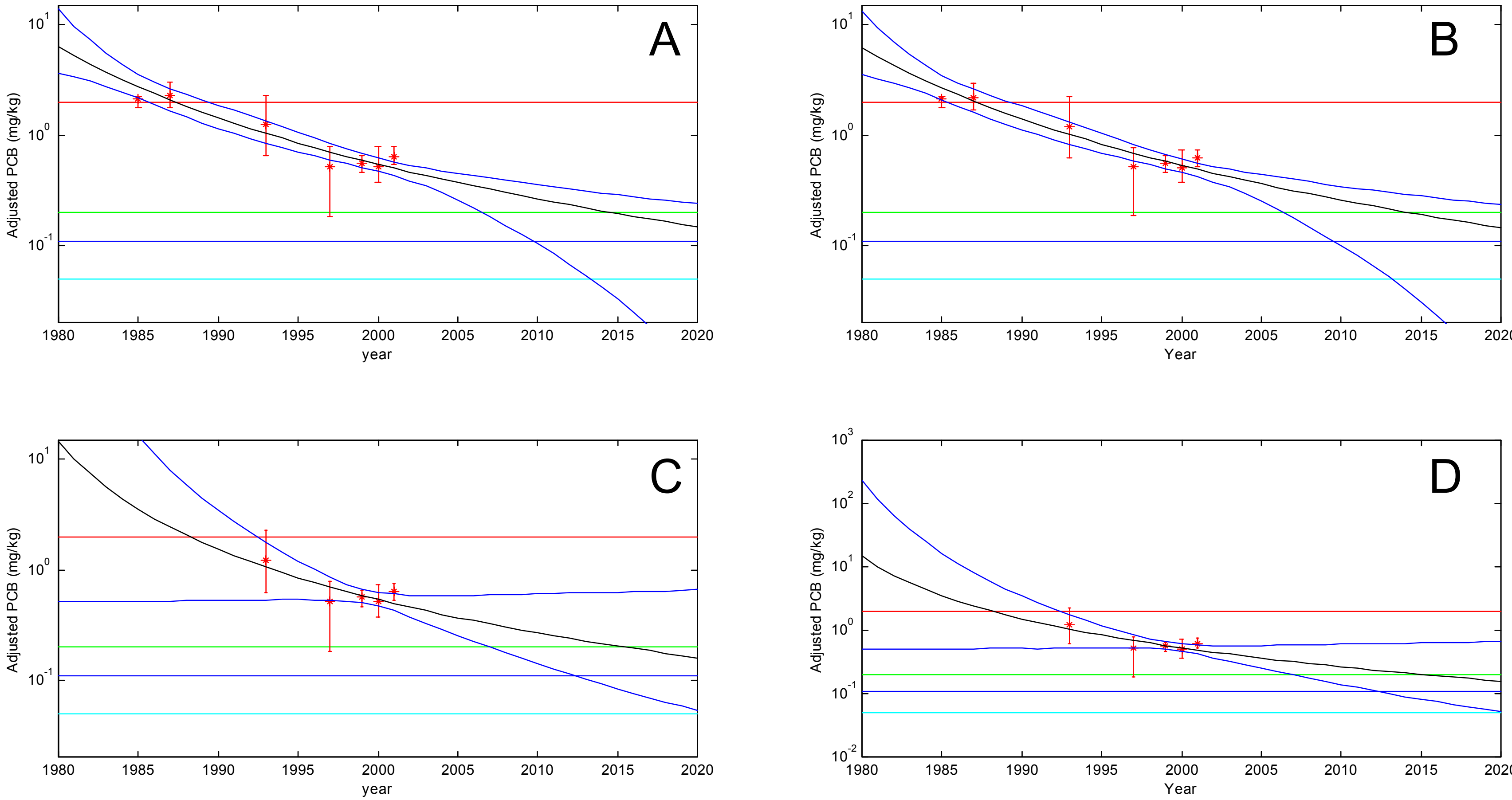


FIGURE 28.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT LAKE ALLEGAN FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).



ABSA-specific Adjusted Data

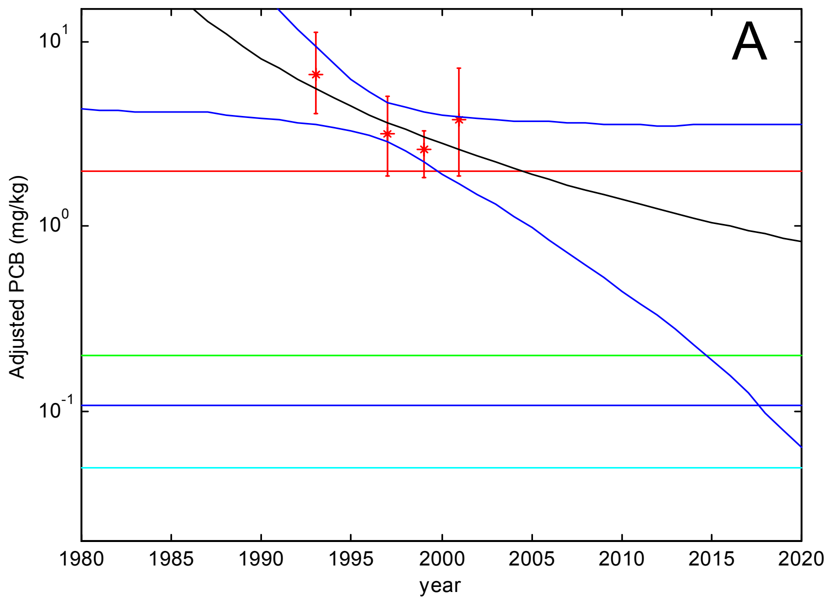
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

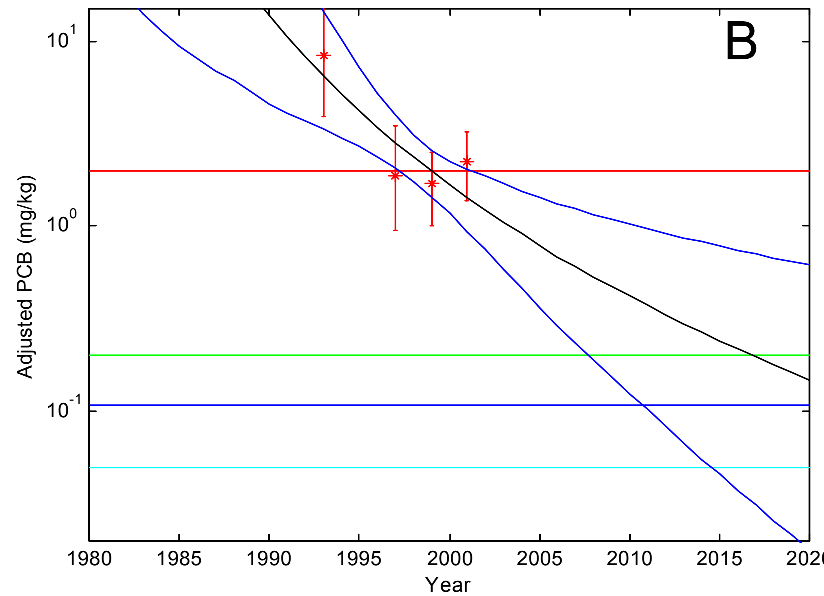
FIGURE 29.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT NEW RICHMOND FOR 1990-2001.



ABSA-specific Adjusted Data



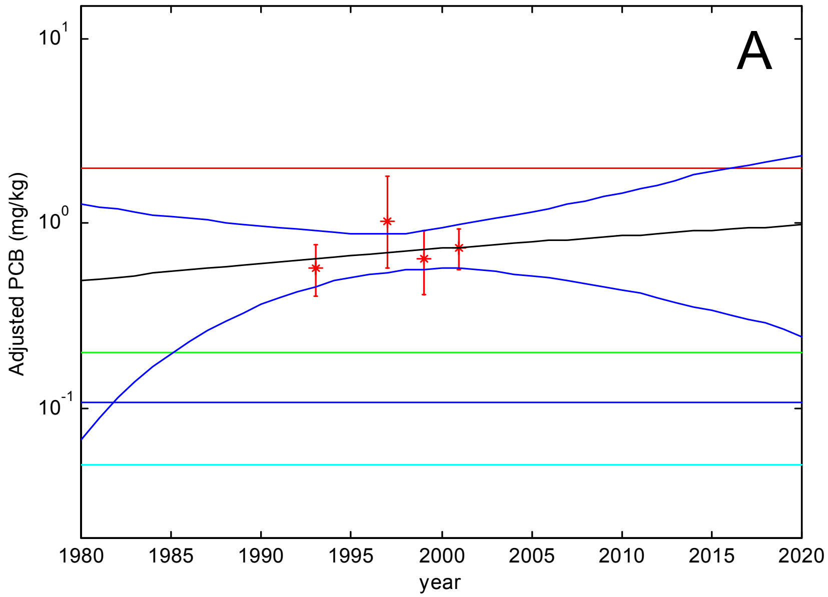
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

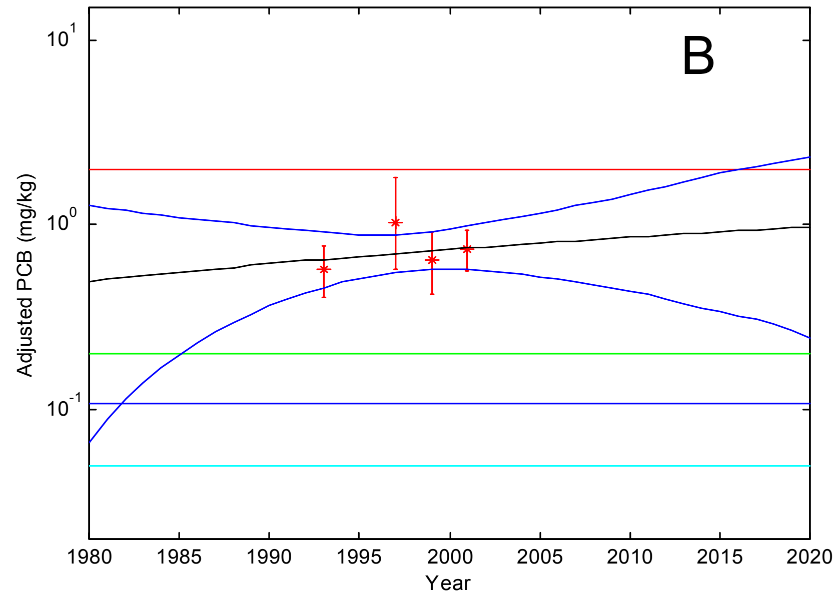
FIGURE 30.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT NEW RICHMOND FOR 1990-2001.



ABSA-specific Adjusted Data



Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 31.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT SAUGATUCK FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).

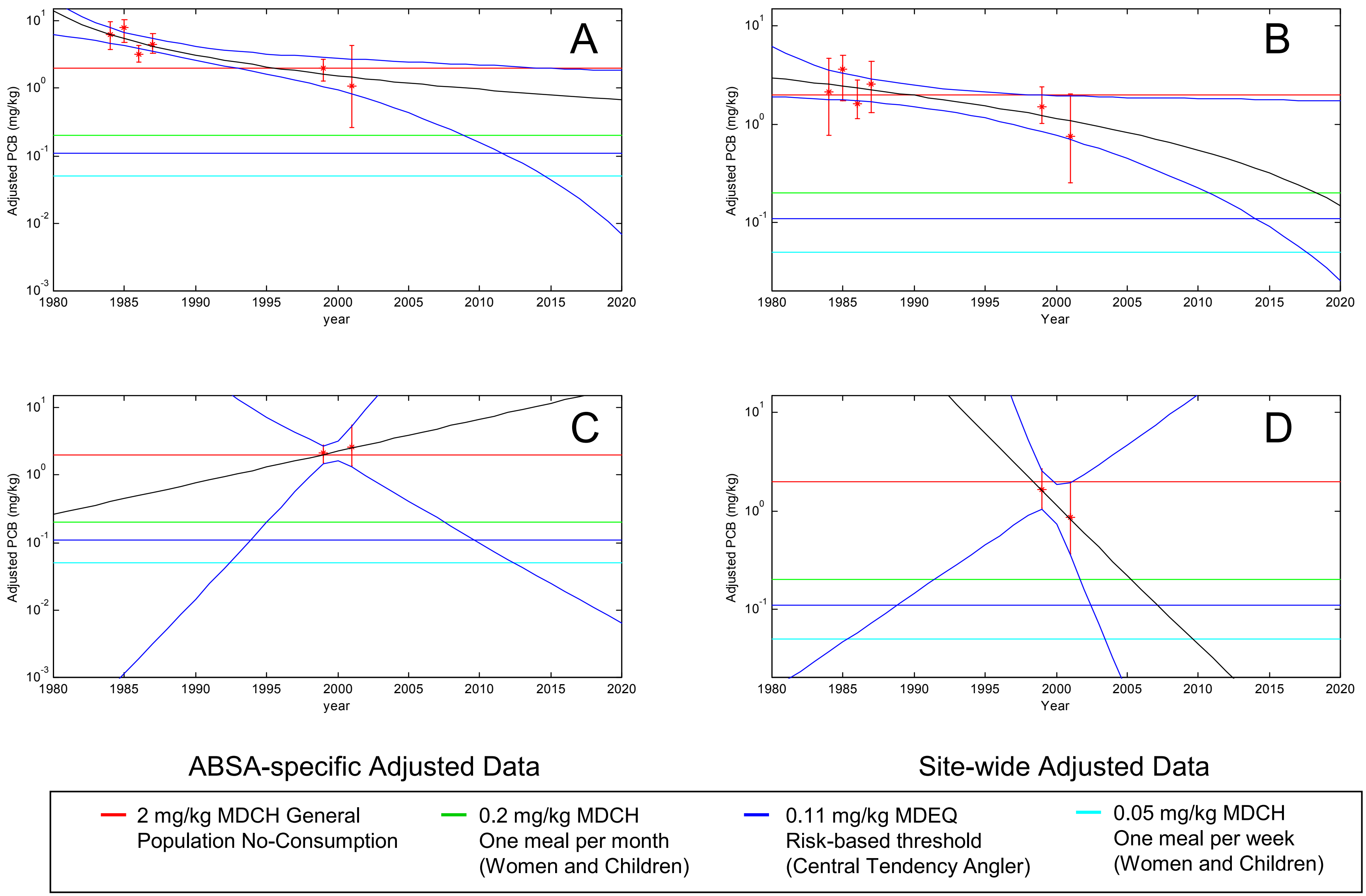
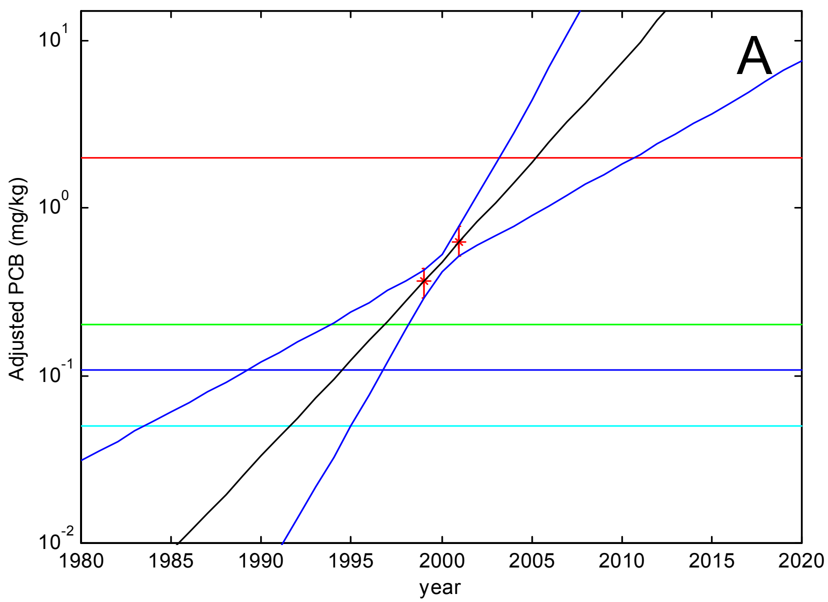


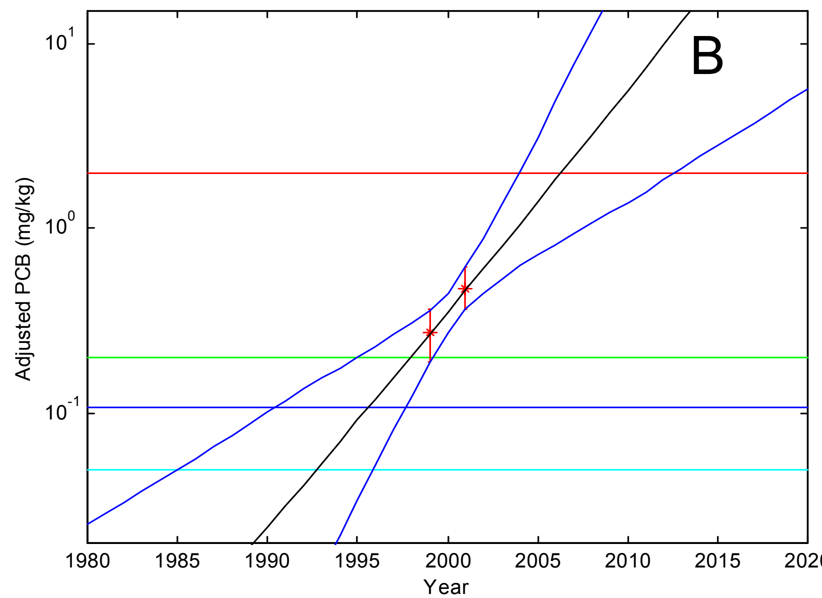
FIGURE 32.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT SAUGATUCK FOR 1990-2001.



ABSA-specific Adjusted Data



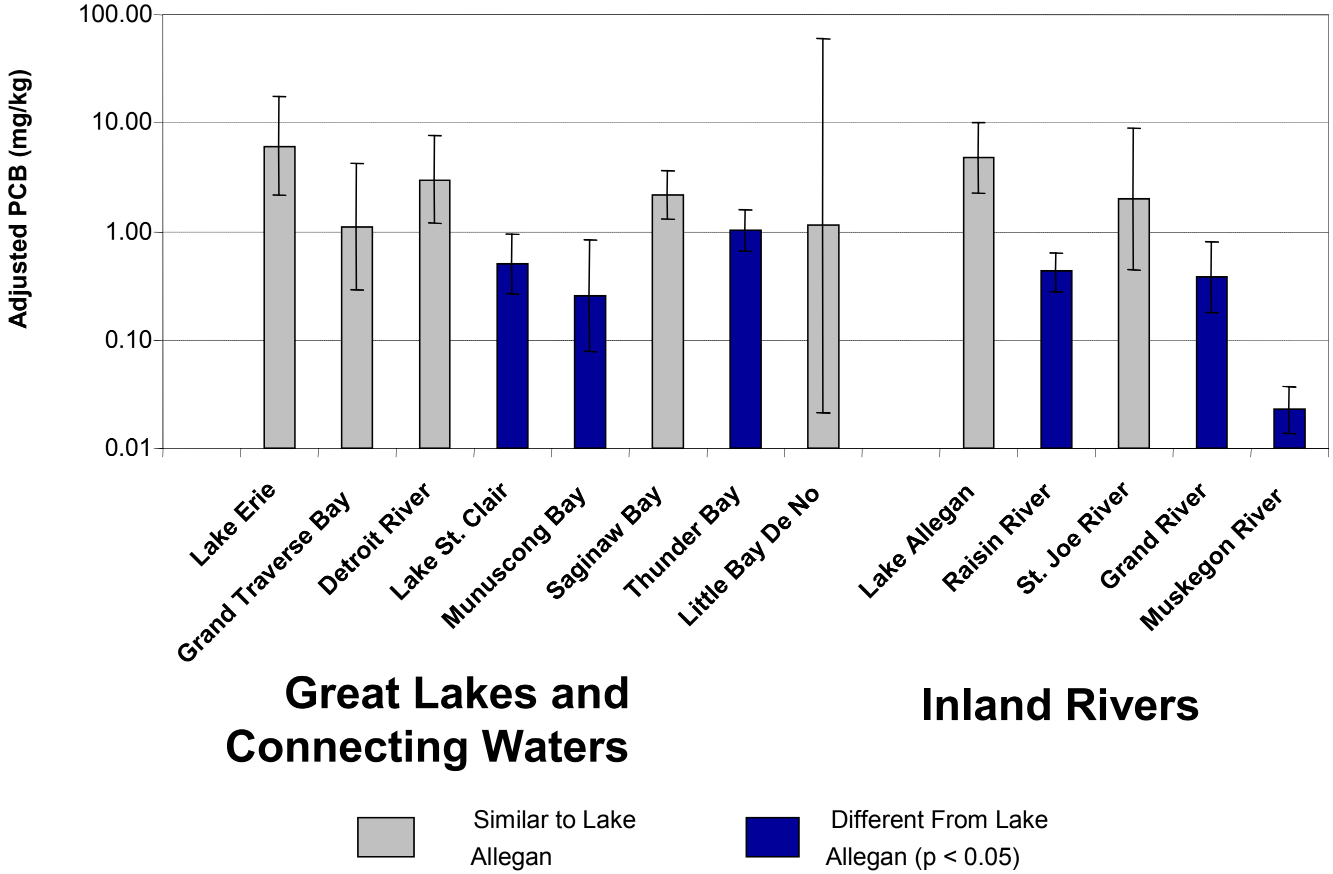
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 33.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED PCB CONCENTRATION IN WHOLE BODY CARP
AT TREND MONITORING STATIONS WITHIN THE STATE OF MICHIGAN



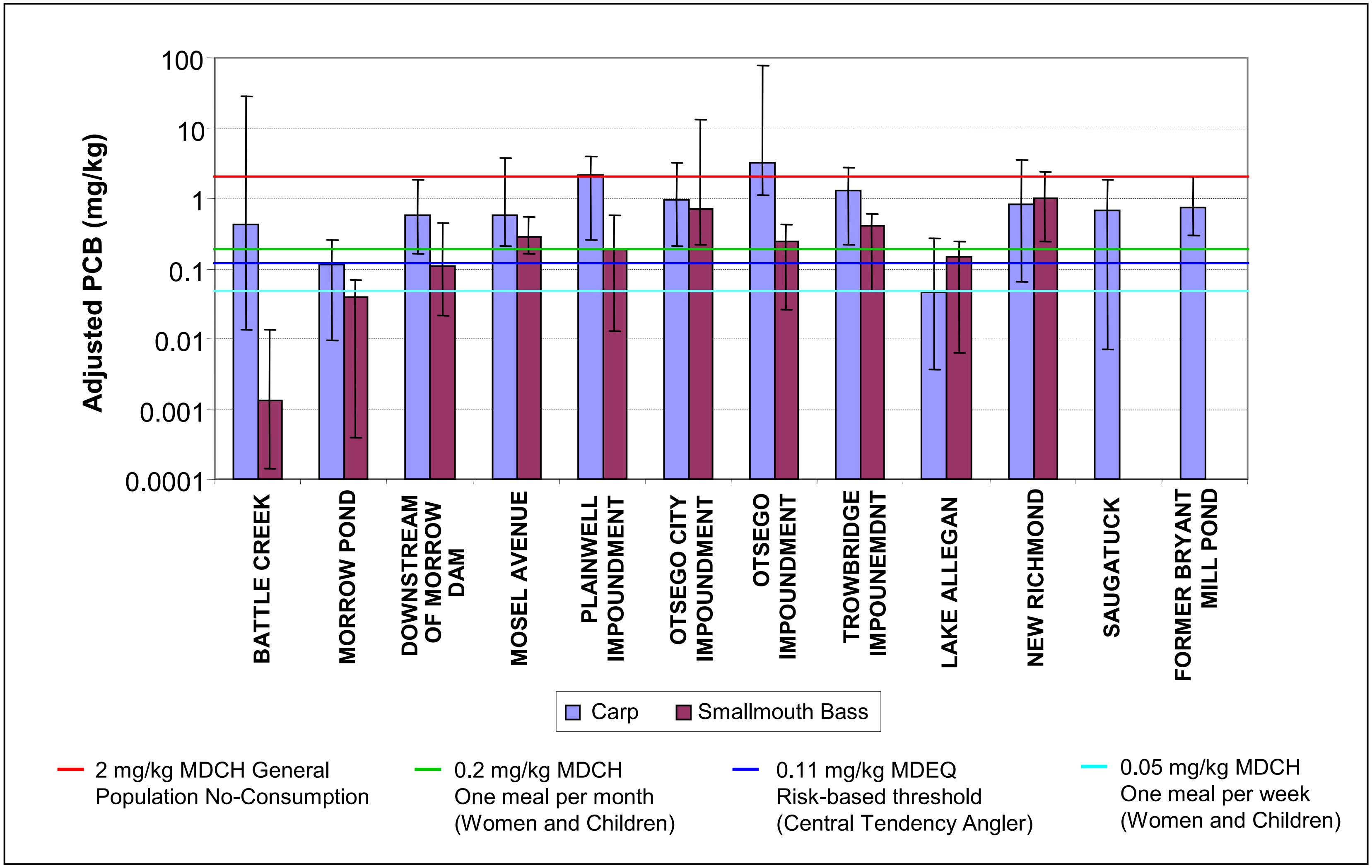
Notes:

1. Bars represent mean length- and lipid-adjusted PCB concentration in whole body carp.
2. Error bars represent 95% confidence limits.
3. White bars represent mean adjusted PCB concentrations that are significantly less than the mean concentration at Lake Allegan at the 5% significance level using Duncan's multiple comparison procedure.

FIGURE 34.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PROJECTED PCB CONCENTRATION IN CARP AND SMALLMOUTH BASS FILLETS IN 2020



Notes:

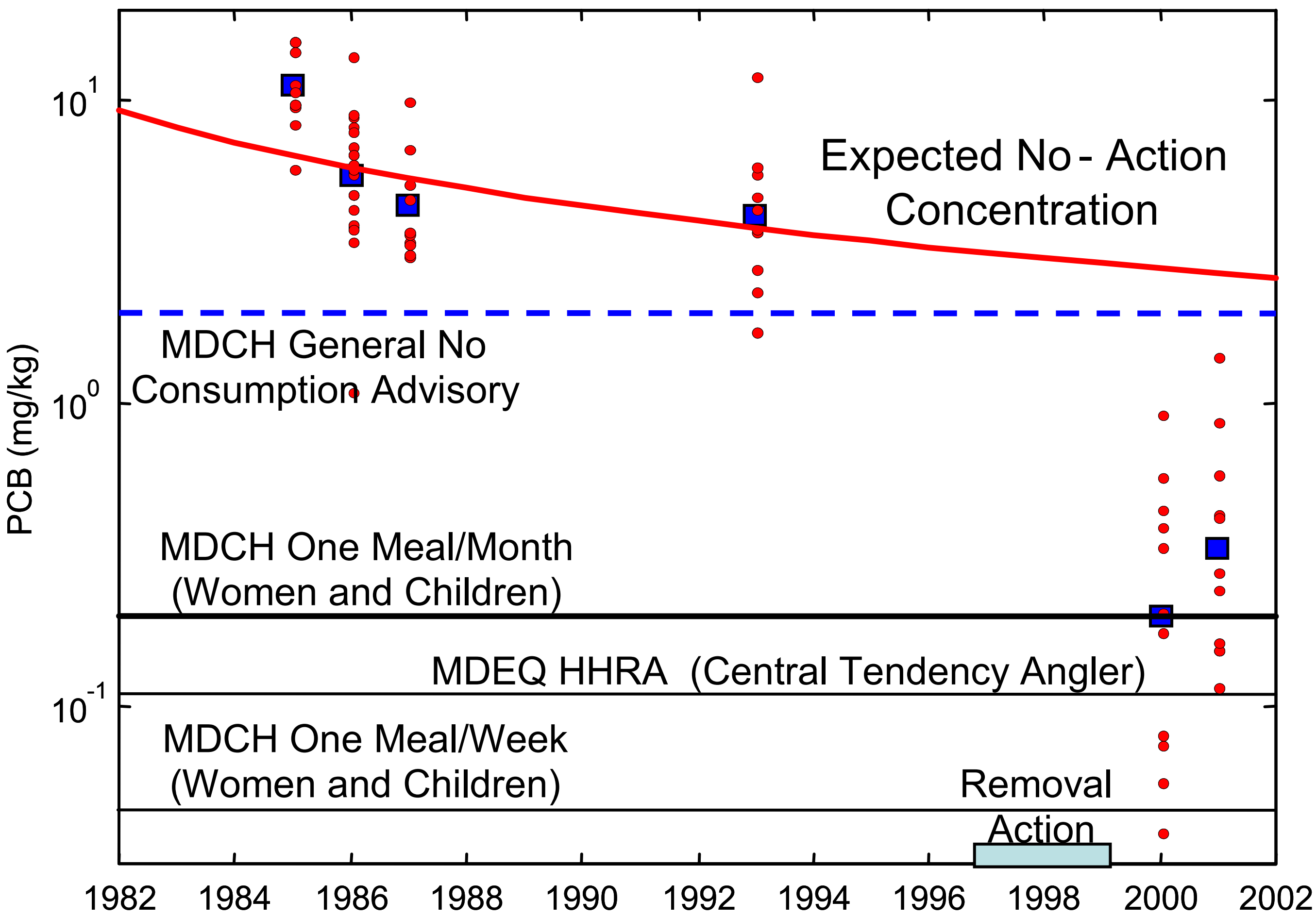
1) Projectied concentrations for Bryant Mill Pond are based on data collected prior to the removal action in 1999 and reflect what would have been expected had the removal not been conducted.

2) Bars represent the best fit MO temporal trend model for the mean, and error bars represent 95% bootstrap confidence intervals..

FIGURE 35.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PERFORMANCE OF INTERIM REMOVAL ACTION AT FORMER BRYANT MILL POND

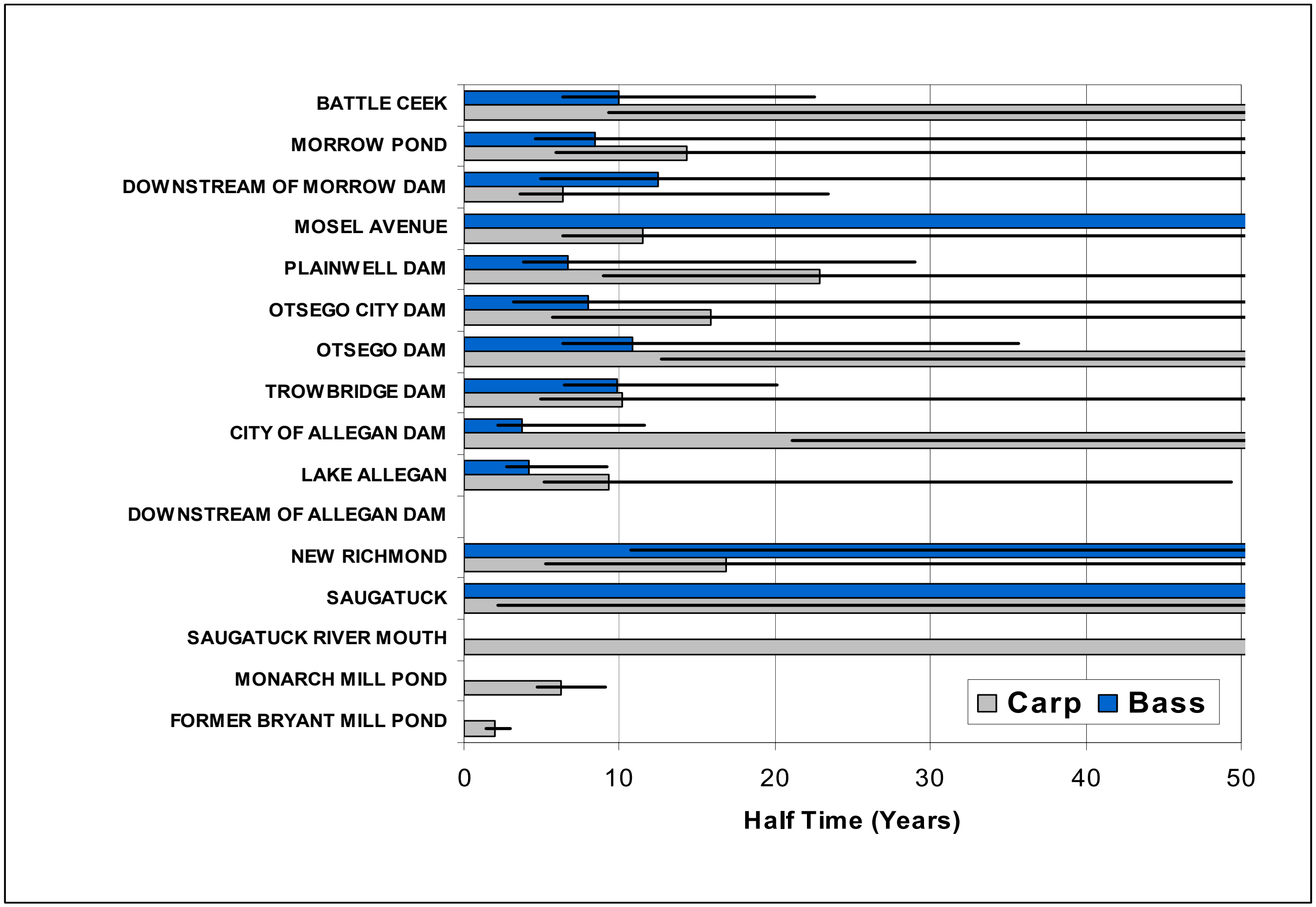


Notes:
1. Red line represents forecasted no-action alternative.

FIGURE 36.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB HALF-TIME IN KALAMAZOO RIVER FILLETS (1990-2001)



Notes:

1. Bars represent estimated half-time and solid lines represent 95% confidence intervals.
2. Bars extending to 50 years indicate that concentrations are not decreasing and therefore there is no half time.
3. Solid lines extending to 50 years indicate that decreasing trends are not significant and therefore upper confidence limits are greater than 50 years.
4. Half-times are adjusted for covariation between PCB concentration, lipid content in samples and fish-length.
5. Monarch Mill and Former Bryant Mill Ponds are listed last because they are on Portage Creek, rather than the Kalamazoo River

Appendix A.

Example Calculations for Lipid- and Length-Adjusted PCB Concentration

PCB concentration was correlated with lipid-fraction ($p < 0.05$) in both Carp and Smallmouth Bass fillets at all sites where trends were estimated (Table 2). Additionally, after adjusting for covariation with lipid-fraction, PCB concentration in carp fillets was correlated with fish-length ($p<0.05$) at Morrow Pond, Plainwell Impoundment, Otsego City Impoundment and Saugatuck. After Adjusting for covariation with lipid-fraction, PCB concentration in smallmouth bass fillets was correlated with fish-length ($p<0.05$) at Battle Creek, Plainwell Impoundment and Saugatuck.

A summary of estimated regression coefficients can be found in Table (3). The reported significance levels are based on the conditional test procedure described by Neter et al (1996). When year-by-lipid or year-by-length interactions were statistically significant, the corresponding main effects were retained in the model, so the statistical significance of those effects is not reported.

These regression coefficients were used to adjust wet-weight PCB data.
Adjusted PCB concentrations are calculated in four steps:

1) Calculate the regression function (predicted concentration) at the observed lipid and length values.

2) Calculate the regression residual by subtracting the predicted concentration from the log of the wet-weight PCB concentration.

3) Calculate the expected concentration for a representative fish by using the regression equation with the site-wide average length and lipid-fraction.

4) Add the residual calculated in (2) to the expected concentration from (3) and finally exponentiate the result to obtain adjusted PCB concentration.

Example 1: Consider a hypothetical smallmouth bass captured at Morrow Pond in 1997 with 0.8 mg/kg wet-weight PCB, 0.4% lipid fraction and 32 cm in length. The model for smallmouth bass at Morrow Pond is

1) Calculate the predicted value

$$Predicted = \beta_0 - \beta_{year} + \beta_{lipid} \times \log(lipid).$$
$$Predicted = 0.43 - 2.26 + 0.71 \times \log(0.4) = -2.4806$$

2) Calculate the residual. The predicted value was already in log-scale, but the actual value was not.

$$Residual = \log(0.8) - (-2.4806) = 2.2575$$

3) Calculate adjustment term based upon site-wide representative smallmouth bass that is 33 cm long and has .696% lipid fraction.

$$Expected_{Site-wide} = 0.43 - 2.26 \times (1) + 0.71 \times \log(0.696) = -2.0856$$

4) Calculate final adjusted value.

$$PCB_{Adjusted} = \exp(-2.0856 + 2.2575) = 1.19$$

Example 2: Consider two hypothetical carp from Saugatuck, each with 2.5 mg/kg wet-weight PCB, 7% lipid fraction and 59 cm in length, but one captured in 1999 and the other captured in 2001. The model for Saugatuck carp is

$$\begin{aligned} Pred_{year} = \beta_0 + \beta_{year} + \beta_{lipid} \times \log(lipid) + \beta_{length} \times \log(length) \\ + \beta_{lipid\times year} \times \log(lipid) + \beta_{length\times year} \times \log(length). \end{aligned}$$

Note that the terms that involve year are different for each year (see Table 3). Following the adjustment procedure and using the values from Table 3, we have:

1) Calculate the regression function (predicted concentration) at the observed lipid and length values for each fish:

$$\begin{aligned} Pred_{1999} = -.68 - 0.08 + 1.31 \times \log(7) + 0.09 \times \log(59) \\ -1.00 \times \log(7) + 0.10 \times \log(59) = .618 \end{aligned}$$

$$\begin{aligned} Pred_{2001} = -.68 - 35.63 + 1.31 \times \log(7) + 0.09 \times \log(59) \\ -1.15 \times \log(7) + 9.0 \times \log(59) = 1.066 \end{aligned}$$

2) Calculate the regression residual:

$$Residual_{1999} = \log(2.5) - .618 = 0.298$$

$$Residual_{2001} = \log(2.5) - 1.066 = -.150$$

3) Calculate the expected concentration for a fish that is representative of the site. Site-wide, the representative carp is 50.876 cm in length and 1.967% lipid fraction.

$$\begin{aligned} Expected_{1999} &= -.68 - 0.08 + 1.31 \times 0.67 + 0.09 \times 3.93 \\ &\quad - 1.00 \times 0.67 + 0.10 \times 3.93 = .194 \end{aligned}$$

$$\begin{aligned} Expected_{2001} &= -.68 - 35.63 + 1.31 \times \log(1.967) + 0.09 \times \log(50.876) \\ &\quad - 1.15 \times \log(1.967) + 9.0 \times \log(50.876) = -.484 \end{aligned}$$

4) Calculate the adjusted values. Note that even though the fish were identical except for capture year, their adjusted values are different. This is because effect of lipid and length on PCB concentration varies from year to year

$$ADJPCB_{1999} = \exp(.298 + .194) = 1.64$$

$$ADJPCB_{2001} = \exp(-.150 - .484) = .530$$

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Section 1
Introduction

The Kalamazoo River drains an approximately 2000-square-mile watershed including nearly 400 miles of tributaries in Southwest Michigan. The lower approximately 80 miles of the river are part of the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. Portage Creek is a tributary joining the Kalamazoo River at Kalamazoo, Michigan, the lower three miles of which are also included in the Site. The presence of polychlorinated biphenyls (PCB) was first reported in the Kalamazoo River and biota of the river in 1971. This consequently resulted in consumption advisories for fish from the Kalamazoo River and Portage Creek. Several subsequent studies have documented the presence of PCB within the surface water, sediments, floodplain soil, and biota of both the Kalamazoo River and Portage Creek, as well as in landfills adjacent to both surface water bodies. In an effort to monitor human-health and ecological risk on the river system, samples of common carp (*Cyprinus carpio*), smallmouth bass (*Micropterus dolomieui*), and a variety of other species have been collected at 17 sites within the Kalamazoo River and Portage Creek.

Assessment of the effectiveness of remedial alternatives on the Kalamazoo River system requires evaluation of future risks to human and ecological health, and quantification of uncertainty in those predictions. Risks result from contact between ecological and human receptors that are of sufficiently long duration and of sufficient intensity to elicit adverse effects (EPA 1992). In this region, human health risks from chlorinated organic compounds such as PCB are primarily associated with ingestion of contaminated fish tissue (Birmingham, et al. 1989; Newhook, et al. 1988; Fitzgerald, et al. 1996). At all superfund sites, a no-action alternative must be evaluated and is the basis to which the cost-effectiveness of other alternatives is compared; this requires an understanding of the likely effect of no action. Among other indices, the National research council (NRC 2001) recommends PCB concentration in fish tissue as an indicator of remedial performance. Therefore, estimates of current and future fish-tissue concentrations are necessary in order to provide a baseline against which other alternatives can be compared. An estimate of uncertainty in these predictions is necessary in order to determine the adequacy of available data to compare competing alternatives.

Temporal trends in the mean or median PCB concentration in fish tissue are typically nonlinear and often modeled as a first order decay process (exponential decay). Stow et al. (1999) pointed out that the first order assumption requires that concentrations decay to zero at a constant rate, precluding the possibility that decay rates may change with time, (or achieve a near steady state nonzero equilibrium). In an effort to correct this weakness, they considered two models for the median PCB concentration in fish tissue; a first order decay model with nonzero asymptote (NZA) and a mixed order model (MO).

$$C_{NZA}(t) = C_F + C_0 \cdot e^{-k\cdot(t-t_0)}; \quad \textit{First Order Decay}$$

$$C_{MO}(t) = \left[C_P{}^{\theta} - k \cdot (t - t_P) \cdot (\theta)\right]^{\frac{1}{(\theta)}}; \quad \textit{Mixed Order Model}$$

The MO model is the solution to the differential equation $dC/dt = kC^{1-\theta}$. Note that when $\theta = 0$ the MO model reduces to first order decay. Although the MO model offers more flexibility than first order decay, model fitting and statistical inferences require more sophisticated methods. Standard least squares and maximum likelihood methods for prediction and quantification of uncertainty cannot be applied to this model because it is neither log-linearizable (Neter et al 1996), nor in the class of generalized linear models (McCullagh and Nelder, 1989) for which substantial theory and application has been developed. Stow, et al. used non-linear least squares to fit the model to their data and to estimate approximate confidence limits. Following Stow, we use the mixed-order model for the decay rate of PCB concentrations in fish tissue samples taken from the Kalamazoo River, but we found nonlinear least squares methods to be inadequate because matrices, required to quantifying uncertainty, were ill-conditioned (Kennedy and Gentle, 1980, p. 34). Profile likelihood methods have been suggested to avoid these numerical instabilities, although, in this instance, we found that profile likelihood tended to underestimate uncertainty in predicted fish tissue concentrations (Goff, Unpublished Data; 2002). As an alternative to non-linear least squares and profile likelihood, we used bootstrap resampling (Efron and Tibshirani, 1986) to estimate uncertainty in modeled estimates of mean PCB concentration in carp and smallmouth bass fillets. Models were fit to data from 13 aquatic biota study areas (ABSA(s)) along the Kalamazoo River and Portage Creek where sample sizes were adequate to estimate temporal trends in concentration.

When analyzing lipophilic contaminants such as PCBs, wet-weight concentrations are often normalized by dividing by the percentage of the sample composed of lipids (ratio method). This lipid normalizing by the ratio method is thought to eliminate the influence of lipid covariation. Hebert and Keenleyside (1995) point out that lipid normalization using ratios may be inappropriate when the relationship between lipids and contaminant concentration cannot be described by a linear regression through the origin. They propose an alternative approach using analysis of covariance (ANCOVA; Neter et al., 1996) both to decide when normalization is appropriate, and to conduct the normalization. We also found that length was sometimes an important predictor of PCB concentrations in fish fillets, so we used a modification of Hebert and Keenleysides approach to simultaneously adjust PCB concentration for covariation with fish-length and fillet lipid-content. Failure to adjust for these potentially confounding factors could lead to misinterpretation of perceived temporal trends due to differences in lipid and or length distributions among years. Because lipid/length associations with PCB varied among years, the data were analyzed in a two stage process where: 1) wet-weight PCB concentrations were adjusted for differential lipid and length within species, ABSA and year combinations; and 2) the mean of these adjusted concentrations was modeled as a MO model in time. Uncertainty in estimates based on this two stage fitting method was quantified using bootstrap re-sampling (Efron and Tibshirani, 1986).

Section 2
Objectives and Rationale

2.1 Objectives

The primary objectives of this report are to: (1) quantify current PCB concentrations in carp and smallmouth bass fillets; (2) describe spatial and recent temporal trends in PCB concentration in carp and smallmouth bass fillets; and (3) describe near future trends in PCB concentration through 2020.

2.2 Rationale

The Kalamazoo River Study Group (KRSG) has used temporal trends in PCB concentration in fish tissue samples from Lake Allegan and Plainwell impoundment to support their hypothesis that natural recovery may be a viable remedial alternative for the Kalamazoo River. KRSG has expressed these temporal trends in terms of half-times which are based on the assumption of a first order decay model. These first-order concentration forecasts require that future PCB concentrations continue to decay at the same average rate that has been observed since the early 1980s. While recent fillet-PCB concentrations are lower than those in the early to mid 1980s, these declines may be due to a combination of factors including: (1) restrictions on manufacture and discharge of PCBs into the environment; (2) active control of PCB sources to the river and; (3) natural recovery. Similar temporal trends have been observed at the Hudson, Fox and Saginaw rivers (NRC, 2001; pp. 201-205) Data collected more recently at some sites suggests that current PCB concentrations at the site may be higher than exponential decay rates would have predicted. Stow et al (1999) noted that decay rates in PCB concentration in salmonids in Lake Michigan were slower in the 1990s than would have been expected under the first order decay assumption. Stow et al. (1999) proposed the mixed order model (MO) as a more flexible alternative to first order models for forecasting near-term temporal trends in PCB concentration. Stow also discussed a first order decay model with nonzero asymptote to estimate trends when decay rates are not constant. They rejected the NZA model due to the unrealistic assumption that PCB concentrations would be required to remain above some non-zero equilibrium concentration indefinitely. Two phase regression models (e.g. spline-regression; Larson, 1992) were also used to model time varying decay rates in fish from the Fox River (Thermo Retec 2001). These two-phase regression models require the assumption of a discrete temporal change-point. Because reduction in PCB sources to most environmental sites have occurred gradually over time (i.e. source reduction and removal actions), the existence of a discrete change-point may not be appropriate. An advantage of the MO time-varying decay rate is that neither an arbitrary change point, nor a perpetually fixed nonzero asymptote is required. Because the first order decay model is a special case, the MO, also provides a framework to test the null hypothesis of first order decay.

Section 3
Methods

3.1 Field Sampling Methods

Common carp and smallmouth bass were collected by the State of Michigan, Blasland Bouck and Lee, Inc., and Camp Dresser and McKee, Inc. by electro-shocking at 17 sites, 15 along the Kalamazoo River and 2 along Portage Creek (Figure 1). Approximately 11 fish of each of the 2 species were collected at a selected subset of sites each year. Some sites were sampled more frequently than others, dependent upon particular monitoring objectives each year. Species other than common carp and smallmouth bass were occasionally caught and retained for analysis. Data associated with each species are summarized in tabular form. Temporal trend analyses that are discussed in the following sections are based on all data collected in these studies. Fish fillet data representing edible portions are collected primarily to evaluate potential exposure of and risk to human consumers. Whole body samples may be more appropriate for analysis of temporal trends, however, due to the limited availability of such samples, temporal trends were estimated using fillet data.

Length and weight were measured and recorded for each fish and the fillets were frozen and delivered to analytical laboratories for analysis of percent lipid and total PCB concentration. The skin was removed from carp fillets and left on smallmouth bass fillets. The resulting data are summarized by site, species, year, and study in Table 1. Length, weight, lipid-fraction, and condition-factor (mass per length cubed) and PCB concentration are plotted in Figures (2) through (7).

3.2 Statistical Methods

PCB concentration in carp and bass fillets was tested for significant covariation with lipid, length, weight, and body condition. PCB concentrations were adjusted for covariation with these factors using multiple regression. To avoid the effects of multicollinearity, lipid-fraction, length, weight, and body condition were also tested pair-wise for correlation and pairs of correlated factors were not included in multiple regression models. These adjusted data were used to estimate temporal trends using the MO model, and uncertainty was estimated using a bootstrapping algorithm (Efron and Tibshirani 1986). This report documents temporal trends in PCB concentration in common carp and smallmouth bass fillets (i.e., edible portions).

3.2.1 Adjusted PCB Concentration

Bioaccumulation of PCBs in organisms is expected to be strongly associated with the lipid-fraction (Landrum and Fisher, 1999). PCB accumulation rates and concentrations may also vary with age and condition of organisms due to changes in dietary loads as well as dilution effects related to fish growth. Because inter-annual variation in length, lipid, weight, and condition (K%mass/Length^3) could bias and or confound perceived temporal trends in PCB concentration, we adjusted PCB concentration for these factors when effects were found to be statistically significant at the 0.05 level of significance. Factors that were significant predictors of PCB concentration, and not inter-correlated were included in final models.

Fillet data were adjusted in two ways:

1) based on overall site-wide average lipid; and
2) based on ABSA-specific average lipid and length.

Adjustment method (1) is appropriate to compare exposure of fish to PCBs (the exposure that fish receive). These adjusted concentrations are appropriate for comparing PCB concentrations and attenuation rates among ABSA and years.

Adjustment method (2) provides an estimate of the exposure that human fish consumers would expect to receive on average. These adjusted concentrations are appropriate for temporal comparison of PCB concentrations within ABSA. They can also be used to calculate the expected exposure associated with fish consumption. Adjusted concentrations based on methods (1) and (2) are similar for ABSA where the length/lipid distribution is similar to the population as a whole. If the lipid/length distribution varies significantly from the overall distribution, adjustment methods (1) and (2) will tend to differ.

Because of the well documented dependence between lipophilic contaminants such as PCB and lipid content, we first tested for a significant correlation between PCB concentration and lipid content before testing for other effects. To avoid the effects of multi-collinearity (Neter et al 1996), weight and body condition were not included in the regression models. PCB-Lipid-length relationships were represented as the log linear model

$$\log(C_k) = \beta_0 + \beta_1 \times \log(Lipid_k) + \sum_{i=2}^{p+1} \beta_i \times (year_{ik}) + \sum_{j=p+2}^{2p+1} \beta_j \times \log(Lipid_k) \times (year_{jk})$$

$$+ \beta_{2p+2} \times \log(length_k) + \sum_{j=2p+3}^{3p+2} \beta_j \times \log(Length_k) \times (year_{jk}) + \varepsilon_k \qquad (1)$$

$$k = 1,2,3 \ldots n$$

where C_k represents tissue PCB concentration in the k^{th} fish, $year_{ik}$ is a discrete indicator variable equal to 1 in the i^{th} year and 0 otherwise, $lipid_k$ and $length_k$ represent the lipid content and length of the k^{th} fish respectively.

This model amounts to fitting a multiple linear regression between the natural log of concentration and the natural log of lipid and length, within each year, ABSA and species combination. In situations where the regression is through the origin, and the length effect is not significant, this is analogous to lipid normalizing using the ratio method (i.e. dividing each PCB concentration by the corresponding lipid fraction; Hebert and Keenleyside 1994).

Predictors that were found to be significant were used to adjust wet-weight PCB concentration in two ways: (1) based on long term averages for data pooled across all ABSA; and (2) based on long term averages within each ABSA. The adjusted data were calculated as follows.

Equation (1) can be rewritten in matrix form as $\mathbf{C} = Exp(\mathbf{X\beta}) \times \boldsymbol{\varepsilon}'$ where X is the design matrix containing the year effects and lipid and length effects found to be significant at the 0.05 level, $ is the vector of regression coefficients estimated by linear least squares (Neter et al 1996), and $\boldsymbol{\varepsilon}'$ is a vector of lognormally distributed errors with mean 1 and variance F. Define $\mathbf{R} = \log(\mathbf{C}) - \mathbf{X}\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\beta}}$ to be the vector of residuals and estimated regression coefficients respectively. Also define $\mathbf{X}_{rep}$ to be a vector containing the lipid and length measurements for a representative fish. For adjustment method (1) $\mathbf{X}_{rep}$ contained the mean length and lipid (natural log scale) for all fish of a particular species averaged over all years and ABSA (site-wide). For adjustment method (2) $\mathbf{X}_{rep}$ contained the mean length and lipid (natural log scale) for fish of a particular species averaged over all years within each ABSA. The vector of adjusted PCB concentration is $\mathbf{C}_{adjusted} = \exp(R + \mathbf{X}_{rep}\hat{\boldsymbol{\beta}})$.

3.2.2 Spatial Trends

Adjusted PCB concentrations were summarized for each ABSA in Table 1. Average site-wide adjusted concentrations were also plotted for each year for Battle Creek, Plainwell Impoundment, Lake Allegan and New Richmond.

3.2.3 Temporal Trends

We fit the MO model to the adjusted PCB concentrations $\mathbf{C}(t)_{adjusted} = MO(t)$, estimating the parameters by maximum likelihood assuming a lognormal error. The overall model is of the form $C(t) = e^{\mathbf{X\beta}} MO(t)\varepsilon'$. We used this two stage fitting process to allow the coefficients on lipid and length to vary with year within each ABSA. The variance and confidence limits of parameter estimates and future predictions was estimated using a bootstrapping algorithm where fish were resampled with replacement within each species, ABSA and year combination. One thousand bootstrap samples were drawn for each species, ABSA combination. Fitted models, estimated means and confidence limits were plotted for carp and smallmouth bass for each ABSA. The MO model was used to project future concentrations with confidence limits from 2002 through 2020. Projections were estimated based on all data (Model I) as well as a subset of data restricted to post-1990 samples (Model II) to evaluate the sensitivity of projections to samples collected in the 1980s. Finally, first order decay models were also fit to the adjusted data, and the half-time and confidence limits were estimated and plotted.

3.2.4 Comparison of Lake Allegan and Other State Sites

We compared length- and lipid-adjusted PCB concentration in whole-body carp samples from Lake Allegan with whole body carp samples from 7 trend monitoring sites on great lakes and connecting waterways and 4 sites on inland rivers. Like the Lake Allegan, each of the inland river sites was located upstream of the dam closest to each rivers confluence with a great lake. This excluded fish that could have migrated from the great lakes, where PCB concentrations are often higher than in inland waterways (Personal communication, Robert Day). The great lakes sites included Lake Erie, Grand Traverse Bay, Detroit River, Lake St. Clair, Munuscong Bay, Saginaw Bay, and Thunder Bay. The inland sites included the Raisin, St. Joe, Grand and Muskegon Rivers. Adjusted PCB concentrations were compared using Dunnett’s procedure (Dunnett 1955) for comparing several means to a single control. Dunnett’s procedure was used to control the maximum experimentwise Type I error rate at the 5% significance level. Type I errors occur when the null hypothesis of no difference among sites is not rejected when in fact a difference actually exists. Because sites were not sampled every year, data were from 1997, 1998 and 1999 were combined for analysis.

Section 4
Results

4.1 General Results

At most sites, wet-weight PCB concentrations in carp and smallmouth bass fillets were lower in 2000/2001 than in the mid to late 1980s.

Average adjusted PCB concentrations were summarized in Table (1) in 4 ways. Data were adjusted using ABSA-specific average length and lipid and site-wide average length and lipid, and adjustments were applied based on fish collected from 1983-2001 (Model I) and those collected from 1990 through 2001 (Model II). Site-wide adjusted PCB concentrations for Model I were plotted in Figure (8). These adjusted data indicate the PCB concentration to which fish are exposed, and are appropriate for comparing site conditions among ABSA and years. Recall each ABSA is a discrete river segment typically bounded by dams which reduce migration of fish among ABSAs. Fish collected from most ABSAs can be considered indicators of conditions in each of these discrete river segments.

Site-wide and ABSA-specific length- and lipid-adjusted PCB concentrations for Model I are plotted for Carp and Smallmouth Bass in 2001 in Figures (9) and (10) respectively. These concentrations represent the expected bioaccumulation of fish and the expected exposure to fish consumers respectively in 2001. Fitted models (Model I and Model II) are plotted for each ABSA-Species combination in Figures (11) through (32).

Wet-weight PCB concentration in fillets is representative of the exposure a fish consumer would have received from a particular cohort of fish in a particular year. However, to apply this information to risk assessment the consumers "expected" exposure over a period of years may be more important. To estimate this expected exposure for fish from each ABSA, PCB concentration was adjusted to be representative of a fish with average length and lipid-fraction. Provided that length and lipid distributions remain stable over long periods of time, these adjusted concentrations are representative of long-term exposures that fish consumers would be expected to receive. Following is a summary of wet-weight and ABSA-specific adjusted PCB concentration for carp and smallmouth bass fillets from the Kalamazoo River and Portage Creek.

Average wet-weight and lipid- and length-adjusted PCB concentrations in carp and smallmouth bass fillets continue to be higher at ABSAs within the superfund site than at Battle Creek. Currently (2001) wet-weight PCB concentrations average 0.40 mg/kg in carp and 0.06 mg/kg in smallmouth bass at Battle Creek. At ABSAs within the superfund site, average wet-weight concentration in carp fillets ranges from 1.49 mg/kg at Lake Allegan to 9.80 mg/kg at Plainwell Impoundment. PCB concentration in smallmouth bass fillets at ABSA within the superfund site range from 0.46 mg/kg at Otsego City Impoundment to 1.20 mg/kg at Trowbridge Impoundment. In general, PCB concentration in carp and smallmouth bass fillets from ABSA within the superfund site remain 1 to 2 orders of magnitude higher than those from the reference area, Battle Creek.

Lipid, length and weight distributions of fish collected from the ABSAs were found to vary temporally, although trends were not consistent among ABSAs (Figures 2 through 5). For example, lipid, length and weight in carp increased from the 1980s through 2001 at Plainwell Impoundment, while these same metrics decreased at New Richmond. Temporal trends in body condition also varied among sites. Condition of carp and smallmouth bass at Battle Creek increased over the period of study while body condition in carp and smallmouth bass decreased at New Richmond.

PCB concentration and percent lipid were correlated at all ABSAs, while association between PCB concentration and length varied by ABSA. For example, at Lake Allegan, carp fillet PCB concentration tracks fluctuations in lipid fraction, while association with length is less consistent (Figure 7). Because PCB concentration is associated with spatially and temporally variable lipid-fraction and, at times, fish-length, spatial and temporal comparisons, and temporal projections should be based on lipid and/or length adjusted PCB concentrations. The following sections describe analysis of spatial and temporal trends in adjusted fillet-PCB concentration.

4.2 Lipid and Length Adjustments

PCB concentration was correlated with lipid-fraction ($p < 0.05$) in both Carp and Smallmouth Bass fillets at all sites where trends were estimated (Table 2). Additionally, after adjusting for covariation with lipid-fraction, PCB concentration in carp fillets was correlated with fish-length ($p<0.05$) at Morrow Pond, Plainwell Impoundment, Otsego City Impoundment and Saugatuck. After Adjusting for covariation with lipid-fraction, PCB concentration in smallmouth bass fillets was correlated with fish-length ($p<0.05$) at Battle Creek, Plainwell Impoundment and Saugatuck.

A summary of estimated regression coefficients can be found in Table (3). The reported significance levels are based on the conditional test procedure described by Neter et al (1996). When year-by-lipid or year-by-length interactions were statistically significant, the corresponding main effects were retained in the model, so the statistical significance of those effects is not reported. These regression relationships were used to adjust wet-weight PCB concentration.

4.3 Expected Exposure for Fish Consumers

The Michigan Department of Community Health (MDCH) has established criteria for placing fish on the Michigan Sport Fish consumption Advisory. The criteria for the general population differ from that for sensitive populations -- women of childbearing age and children under 15 years of age).

General Population

For the general population, when between 11 and 49 percent of samples exceed 2 mg/kg in fish, a one-meal/week advisory is issued; when greater than 50 percent of fish samples exceed 2 mg/kg, a no consumption advisory is issued.

Sensitive Population

For women of childbearing age and children under 15 years of age, at concentrations greater than 0.05 mg/kg up to 0.2 mg/kg of PCBs in fish, a one-meal /week advisory is issued. At concentrations greater than 0.2 mg/kg, up to 1 mg/kg of PCBs in fish, a one-meal/month advisory is issued. At concentrations greater than 1.0 mg/kg up to 1.9 mg/kg in fish, a six-meal/year advisory is issued. At concentrations above 1.9 mg/kg, a no consumption advisory is issued.

Risk Based Cleanup Goal

The MDEQ has also established 0.11 mg/kg PCBs in fish as a cleanup goal protective of central tendency anglers. In the following sections observed PCB concentrations are compared with these MDCH criteria and the MDEQ risk based cleanup goal. For comparative purposes, the MDCH 2-, 0.2-, and 0.05-mg/kg criteria and the 0.11-mg/kg cleanup goal are indicated on Figures (11) through (33) with horizontal lines.

4.3.1 Battle Creek

Carp

Since 1987, PCB concentration in fillets ranged from a minimum of less than detection limits (approximately 0.05 mg/kg) to a maximum of 1.2 mg/kg. Over this same period, average wet-weight fillet PCB concentration ranged from 0.08 to 0.4. In all years, average and maximum PCB concentrations were below the 2 mg/kg Michigan Department of Community Health general consumption advisory limit. In all but 2 years (1991 and 2001) average concentration was below the 0.2 mg/kg MDCH advisory level of one-meal-per-month for women and children. Average wet-weight concentrations exceeded the MDEQ 0.11 mg/kg risk-based cleanup goal protective of central tendency sport anglers (CDM 2001) in 1987, 1991, 2000 and 2001.

Adjusted PCB concentration in carp fillets was sometimes higher and sometimes lower than wet-weight concentration depending on the lipid and length of individual fish. As with wet-weight PCB concentrations, average adjusted PCB concentrations never exceeded the 2 mg/kg MDCH general consumption advisory level. Adjusted concentrations exceeded the 0.2 mg/kg MDCH advisory level for women and children and the MDEQ HHRA tendency angler level in 1991 (0.67 mg/kg) and 2001

(0.41 mg/kg). Average adjusted PCB concentration also exceeded central tendency sport angler limit in 1997 (0.19 mg/kg).

Smallmouth Bass
Since 1997, wet-weight PCB concentration in individual smallmouth bass fillets never exceeded any of the MDCH criteria nor the risk-based-cleanup goals Average wet-weight PCB concentration slightly exceeded the MDEQ risk-based level for the central tendency angler (0.11 mg/kg) in 1993 (0.13 mg/kg). After adjusting for covariation with lipid and length, average adjusted PCB concentration in smallmouth bass fillets never exceeded the MDCH general consumption-, one-meal-per-month for women and children-criteria, nor the MDEQ risk-based cleanup goal for the central tendency anglers.

4.3.2 Morrow Pond

Carp
Since 1985, PCB concentration in fillets ranged from a minimum of 0.06 in 1997 to a maximum of 12.7 mg/kg in 1986. Over this same period, average wet-weight fillet PCB concentration ranged from 0.22 in 1999 (LTM sampling) to 3.46 in 1986. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in 1985 and 1986. Average wet-weight PCB concentration exceeded the 0.2 mg/kg MDCH advisory level of one-meal-per-month for women and children and the 0.11 mg/kg risk-based cleanup goal protective of central tendency sport anglers in every year sampled from 1985 through 2001.

Average adjusted PCB concentration ranged from 0.25 mg/kg in 1999 to 3.33 mg/kg in 1986. As with wet-weight concentrations, adjusted average concentrations also exceeded the 0.2 mg/kg MDCH advisory level of one-meal-per-month for women and children and the 0.11 mg/kg risk-based cleanup goal protective of central tendency sport anglers in every year sampled from 1985 through 2001.

Smallmouth Bass
Wet-weight PCB concentration in individual fish ranged from a minimum of 0.03 mg/kg in 1997 to a maximum of 1.44 mg/kg in 1985. Average wet-weight PCB concentration never exceeded the 2 mg/kg MDCH general consumption advisory level, but exceeded the MDEQ risk based central tendency angler cleanup goal of 0.11 mg/kg in 1985 through 1999. Average wet weight PCB concentrations have been slightly below the 0.2 mg/kg MDCH-criteria since 1993. Average PCB concentration in 2001 (0.07 mg/kg) was below the MDEQ risk based cleanup goal of 0.11 mg/kg.

Average adjusted concentrations ranged from 0.09 in 2001 to 1.17 in 1985. Average adjusted concentrations exceeded the MDEQ risk-based cleanup goal in 1993 through 1999, but were below the MDCH advisory limit for one-meal-per-month for women and children (0.20 mg/kg). As with wet-weight concentrations, average adjusted PCB concentration (0.09 mg/kg) was below the 0.11 mg/kg MDEQ risk-based limit in 2001.

Other Species
One channel catfish (*Ictalurus punctatus*) captured in 2001, had 0.34 mg/kg wet-weight PCB concentration, exceeding the 0.2 mg/kg criteria. Three largemouth bass (*Micropterus salmoides*) were captured in 1985, had wet-weight PCB concentration ranging from 1.16-, to 1.95-, averaging 1.55-mg/kg.

4.3.3 Downstream of Morrow Dam

Carp
The area from Morrow Dam to the confluence of Portage Creek and the Kalamazoo River was sampled in 1993 by KRSG and in 2000 by MDEQ as part of the LTM. The area was sampled in 2001 as part of the LTM, but no carp were captured. Eleven carp were caught in 1993 with PCB concentration ranging from 1.3 mg/kg in 2001 to 8.2 mg/kg in 1993. Average PCB concentration was 2.95 mg/kg in 2000 and 4.43 mg/kg in 1993. These PCB levels exceed the general consumption advisory level of 2.0 mg/kg.

Average adjusted PCB concentrations were similar to wet-weight concentrations, 2.38 mg/kg in 2000 and 4.69 mg/kg in 1993.

Smallmouth Bass
Eleven smallmouth bass were caught in both 1993 and 2000, and 1 additional fish was caught in 2001. Wet-weight PCB concentration ranged from a minimum of 0.06 mg/kg in 2000 to 3.23 mg/kg in 1993. Average wet-weight PCB concentration was 0.25 mg/kg in 2000 and 1.09 mg/kg in 1993, an apparent 4 fold reduction in wet-weight PCB concentration.

Average adjusted PCB concentration was less variable, ranging from 0.39 mg/kg in 2000 to 0.61 mg/kg in 1993, an approximate 36% reduction. This indicates that much of the 4-fold reduction in wet weight concentration was due to variation in length and lipid. Average adjusted PCB concentrations were below the MDCH general consumption advisory but above the MDCH advisory for women and children, and the MDEQ risk-based advisory levels.

Other Species
One northern pike (*Esox, lucius*) and one rock bass (*Ambloplites, rupestris*) were captured with wet-weight PCB concentrations of 0.43- and 0.05-mg/kg respectively.

4.3.4 Mosel Avenue

Carp
Wet-weight PCB concentration in fillets ranged from a minimum of 0.98 in 1983 to a maximum of 21.70 mg/kg in 1999. Over this same period, average wet-weight fillet PCB concentration ranged from 3.15 in 1983 to 7.76 in 2000. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years for which data are available, 1983, 85, 86, 93, 99, and 2000.

Average adjusted PCB concentration ranged from 2.17 mg/kg in 1999 to 6.52 mg/kg in 1985. As with wet-weight concentrations, adjusted average concentrations also exceeded the 2.0 mg/kg MDCH general consumption advisory in all years for which data are available.

Smallmouth Bass

Wet-weight PCB concentration ranged from a minimum of 0.16 mg/kg in 1993 to a maximum of 2.35 mg/kg in 2000. Average wet-weight PCB concentration never exceeded the 2 mg/kg MDCH general consumption advisory level, but exceeded the 0.20 mg/kg MDCH one-meal-per-month advisory level for women and children in all years for which data are available (1985, 93, 99 and 2000).

Average adjusted concentrations ranged from 0.49 in 1993 to 3.76 in 1985. Average adjusted PCB concentrations exceeded the MDCH advisory limit of one-meal-per-month for women and children in all years in which data area available (1985, 1993, 1999 and 2000) and exceeded the general consumption advisory in 1985.

Other Species

Eleven pumpkinseed sunfish (*Lepomis gibosus*) were captured in 1999 and had wet-weight PCB concentration ranging from 0.18- to 0.60 mg/kg with average concentration of 0.35 mg/kg, exceeding the MDCH one-meal per month advisory for women and children.

4.3.5 Plainwell Impoundment

Carp

Since 1983, wet-weight PCB concentration in fillets ranged from a minimum of 0.50 in 1986 to a maximum of 21.54 mg/kg in 1999. Over this same period, average wet-weight PCB concentration ranged from 4.13 in 1986 to 10.33 in 1999. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years for which data are available from 1983 through 2001.

Average adjusted PCB concentration ranged from 3.01 mg/kg in 2001 to 9.15 mg/kg in 1985. As with wet-weight concentrations, adjusted average concentrations also exceeded the 2.0 mg/kg MDCH general consumption advisory level in every year sampled from 1983 through 2001.

Smallmouth Bass

Wet-weight PCB concentration ranged from a minimum of 0.09 mg/kg in 1997 to a maximum of 3.89 mg/kg in 1993. Average wet-weight PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory level in 1985 (3.25 mg/kg) and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Average adjusted PCB concentration ranged from 0.23 mg/kg in 1997 to 1.11 mg/kg in 1993. Adjusted average concentration exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

4.3.6 Otsego City Impoundment

Carp

Carp samples were collected from Otsego City Impoundment in 1993, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.30 in 2001 to a maximum of 8.03 mg/kg in 1993. Over this same period, average wet-weight PCB concentration ranged from 1.11 in 1999 to 3.44 in 1993. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in 1993 and 2001 and exceeded the 0.20 mg/kg MDCH one-meal-per-month for women and children in 1999.

Average adjusted PCB concentration ranged from 1.22 mg/kg in 1999 to 3.00 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level in 1993 and 2001 and exceeded the 0.2 MDCH one-meal-per-month advisory for women and children in 1999.

Smallmouth Bass

Wet-weight PCB concentration ranged from a minimum of 0.05 mg/kg in 2001 to a maximum of 3.66 mg/kg in 1993. Average wet-weight PCB concentration exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Average adjusted PCB concentration ranged from 0.98 mg/kg in 2001 to 1.08 mg/kg in 1993. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Other Species

Two channel catfish, 2 northern pike and 1 walleye (*Stizostedium vitrium*) were collected from Otsego City Impoundment. The channel catfish had wet-weight PCB concentrations of 4.74- and 5.40-mg/kg. The northern pike had wet-weight PCB concentrations of 0.06- and 0.84- mg/kg and the walleye had wet-weight PCB concentration of 0.89 mg/kg.

4.3.7 Otsego Impoundment

Carp

Carp samples were collected from Otsego Impoundment in 1993, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.29 in 1999 to a maximum of 49.54 mg/kg in 2001. Over this same period, average wet-weight PCB concentration ranged from 2.54 mg/kg in 1999 to 9.00 mg/kg in 2001. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years in which data are available, Average adjusted PCB concentration ranged from 2.37 mg/kg in 1999 to 3.66 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level (1993, 1999 and 2001).

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.31 mg/kg in 1999 to a maximum of 3.73 mg/kg in 1993. Average wet-weight PCB concentration ranged from 0.58 mg/kg in 1999 to 1.48 mg/kg in 1993 and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

Average adjusted PCB concentration ranged from 0.58 mg/kg in 1999 to 1.03 mg/kg in 1993. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

4.3.8 Trowbridge Impoundment

Carp
Carp samples were collected from Trowbridge Impoundment in 1993, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.64 in 1999 to a maximum of 16.01 mg/kg in 1999. Over this same period, average wet-weight PCB concentration ranged from 3.18 mg/kg in 1999 to 4.55 mg/kg in 1993. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all 3 years for which data are available,

Average adjusted PCB concentration ranged from 2.95 mg/kg in 1999 to 4.82 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level in 1993, 1999 and 2001.

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.43 mg/kg in 1999 to a maximum of 4.19 mg/kg in 1993. Average wet-weight PCB concentration ranged from 0.73 mg/kg in 1999 (BBL samples) to 1.95 mg/kg in 1993 and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

Average adjusted PCB concentration ranged from 1.0 mg/kg in 1999 to 1.59 mg/kg in 1993. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all 3 years sampled.

Other Species
Four channel catfish and were captured from Trowbridge impoundment in 1999 with wet-weight PCB concentration ranging from 1.53- to 5.09-mg/kg. Two northern pike had concentrations 10.2- and 1.41-mg/kg and 1 walleye had 0.64 mg/kg PCB concentration.

4.3.9 City of Allegan Impoundment

Carp

Carp samples were collected from the City of Allegan Impoundment in 1999 and 2001 with wet-weight PCB concentrations ranging from 0.43-to 7.25-mg/kg both in 1999. Average wet-weight PCB concentration was 3.34- and 3.96-mg/kg in 1999 and 2001 respectively. These average concentrations exceed the 2 mg/kg MDCH general consumption advisory level.

Smallmouth Bass

Smallmouth Bass samples were also collected from the City of Allegan Impoundment in 1999 and 2001 with wet-weight PCB concentrations ranging from 0.14-to 0.93-mg/kg both in 1999. Average wet-weight PCB concentration was 0.52- and 0.56-mg/kg in 1999 and 2001 respectively. These average concentrations exceed the 0.20 mg/kg MDCH one-meal-per-month advisory level for women and children.

4.3.10 Lake Allegan

Carp

Carp samples were collected from Lake Allegan Impoundment in 1983 through 1987, 1990, 1992 through 1994, 1997 and 1999 through 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.09 mg/kg to 23.95 mg/kg, both in 1986. Average wet-weight PCB concentration ranged from 0.69 mg/kg in 2000 to 4.43 mg/kg in 1985. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years sampled from 1983, through 1992, and exceeded the 0.2 mg/kg one-meal-per-month limit for women and children from 1992 through 2001.

Average adjusted PCB concentration ranged from 0.73 mg/kg in 2001 to 3.72 mg/kg in 1985. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level in 1985 through 1990, and also in 1994. Average adjusted PCB concentration exceeded the 0.2 mg/kg one-meal-per-month limit for women and children from in all other years.

Smallmouth Bass

Wet-weight PCB concentration ranged from a minimum of 0.10 mg/kg in 2000 to a maximum of 5.80 mg/kg in 1993. Average wet-weight PCB concentration ranged from 0.35 mg/kg in 2000 to 3.29 mg/kg in 1993 and exceeded the 0.2 mg/kg MDCH one-meal-per-month level for women and children in all years sampled.

Average adjusted PCB concentration ranged from 0.51 mg/kg in 2000 (BBL samples) to 2.16 mg/kg in 1987. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Other Species
One black crappie (*Promoxis, nigromaculatus*) was captured in 1999 and 2000 with 1.16- and 0.4-mg/kg wet-weight PCB concentrations respectively. Eight bluegill sunfish (*Lepomis, Macrochirus*) were captured in 1999 with wet-weight PCB concentrations ranging from 0.2- to 0.7- and averaging 0.39-mg/kg. Twelve channel catfish were captured in 1999 with wet-weight PCB concentration ranging from 0.24- to 2.87- and averaging 1.09-mg/kg. Six channel catfish were captured in 2001 with wet-weight PCB concentration ranging from 0.61- to 3.77- and averaging 2.17-mg/kg. Two, 7 and 1 largemouth bass were caught in 1983, 1985 and 2000 respectively. Wet-weight PCB concentration ranged from 0.31 mg/kg in 2000 to 6.54 mg/kg in 1985. Three and 11 northern pike were sampled in 1987 and 1999 respectively, with wet-weight PCB concentration ranging from a minimum of 0.32- to a maximum of 4.60-mg/kg in 1999. Average concentration was 2.36- and 1.81-mg/kg in 1987 and 1999 respectively. Three pumpkinseed sunfish were sampled in 1999 with wet-weight PCB concentration ranging from 0.27- to 0.55-mg/kg. Eleven walleye were sampled in 1999 with wet-weight PCB concentration ranging from 0.18- to 1.53-mg/kg and 2 were sampled in 2000 with wet-weight PCB concentration 0.32- and 1.80-mg/kg. The overall average of these 13 walleye was 0.81 mg/kg, exceeding the MDCH one-meal-per-month advisory level for women and children.

4.3.11 Downstream of Lake Allegan Dam

Carp
Eleven carp samples were collected from the area just downstream of Lake Allegan dam in 1993. Wet-weight PCB concentration in fillets ranged from a minimum of 1.93 mg/kg to a maximum of 17.00 mg/kg. Average wet-weight PCB concentration was 7.6 mg/kg, exceeding the 2 mg/kg MDCH general consumption advisory level.

Smallmouth Bass
Eleven smallmouth bass were also collected in 1993 with wet-weight PCB concentration ranging from 1.05-to 2.42-mg/kg. Average wet-weight PCB concentration was 1.89 mg/kg exceeding the 0.2 mg/kg MDCH one-meal-per-month advisory level for women and children.

4.3.12 New Richmond

Carp
Carp samples were collected from the Kalamazoo River near New Richmond in 1993, 1997, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.20 mg/kg in 1999 to a maximum of 17.3 mg/kg, in 1997. Average wet-weight PCB concentration ranged from 2.55 mg/kg in 1999 to 4.95 mg/kg in 1993. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in all years sampled (1993, 1997, 1999 and 2001).

Average adjusted PCB concentration ranged from 2.39 mg/kg 1999 to 5.90 mg/kg in 1993. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level each year.

Smallmouth Bass
Wet-weight PCB concentration ranged from a minimum of 0.05 mg/kg in 1999 to a maximum of 4.3 mg/kg in 1997. Average wet-weight PCB concentration ranged from 0.54 mg/kg in 1993 to 1.07 mg/kg in 1997 and exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled (1993, 1997, 1999 and 2001).

Average adjusted PCB concentration ranged from 0.60 mg/kg in 2001 to 1.25 mg/kg in 1997. Adjusted average concentration also exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in all years sampled.

Other Species
Two channel catfish were sampled in 1999 with wet-weight PCB concentrations of 1.61- and 1.70-mg/kg. Four flathead catfish (*Pylodictis olivaris*) were sampled in 2001 and had PCB concentrations ranging from 0.60- to 3.32-mg/kg averaging 1.96 mg/kg. Two largemouth bass sampled in 1999 had PCB concentrations of 0.81- and 1.09-mg/kg , and 4 northern pike had PCB concentrations ranging from 0.33- to 0.46-mg/kg with an average of 0.39 mg/kg. Eleven Walleye were sampled in 1999 with PCB concentrations ranging from 0.03- to 0.92-mg/kg averaging 0.28 mg/kg.

4.3.13 Saugatuck

Carp
Carp samples were collected from Kalamazoo Lake and Douglas Bayou near Saugatuck in 1984 through 1987, 1999 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.06 mg/kg in 2001 to 25.70 mg/kg, in 1984. Average wet-weight PCB concentration ranged from 1.63 mg/kg in 2001 to 8.49 mg/kg in 1984. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit each year sampled from 1984 through 1999, and exceeded the 0.20 mg/kg MDCH one-meal-per-month for women and children in 2001.

Average adjusted PCB concentration ranged from 1.20 mg/kg in 2001 to 7.00 mg/kg in 1985. Adjusted average concentrations exceeded the 2.0 mg/kg MDCH general consumption advisory level each year, with the exception of 1999 and 2001 when average adjusted concentrations exceeded the the 0.20 mg/kg MDCH one-meal-per-month for women and children in 2001.

Smallmouth Bass
Smallmouth bass samples were collected from Kalamazoo Lake and Douglas Bayou near Saugatuck in 1985, 1999 and 2001, although only one fish was collected in 1985. Wet-weight PCB concentration ranged from a minimum of 0.20 mg/kg in 1999 to a maximum of 1.71 mg/kg in 1985. Average wet-weight PCB concentration ranged from 0.43 mg/kg in 1999 to 1.71 mg/kg in 1985 and exceeded the 0.2 mg/kg MDCH one-meal-per-month level for women and children in all years sampled (1993, 1997, 1999 and 2001).

Average adjusted PCB concentration was not calculated in 1985 because only one fish was collected. Average adjusted PCB concentration was 0.38 mg/kg in 1999 and 0.61 mg/kg in 2001. Adjusted average concentration exceeded the 0.2 mg/kg MDCH one-meal-per-month for women and children in both 1999 and 2001.

Other Species
Thirteen other species have been collected at Saugatuck since 1984

In 1987 a broad range of 13 other species were collected and analyzed for PCB concentration in edible portions. This included: 10 black crappie (ranging from 0.30- to 1.59- and averaging 0.70-mg/kg) 10 bluegill sunfish (ranging from 0.19- to 0.68- and averaging 0.43-mg/kg), 4 brown trout (ranging from 1.32- to 4.62- and averaging 3.73-mg/kg), 8 channel catfish (ranging from 3.45- to 12.41 and averaging 6.36-mg/kg), 3 flathead catfish (ranging from 1.71- to 22.20- averaging 13.71-mg/kg), 10 largemouth bass (ranging from 0.52- to 2.02- averaging 1.10-mg/kg), 10 northern pike (ranging from 0.36- to 3.36- and averaging 1.33-mg/kg), 10 rainbow trout (*Oncorhyncus, mykiss*) (ranging from 0.24- to 0.73- and averaging 0.44-mg/kg), 10 rock bass (ranging from 0.17- to 0.52- and averaging 0.37-mg/kg), 10 walleye (ranging from 0.33- to 1.48- and averaging 0.58-mg/kg), 10 white sucker (ranging from 0.44- to 2.82- and averaging 1.08-mg/kg) and 10 yellow perch (ranging from 0.06- to 1.20- and averaging 0.43-mg/kg).

For those species that were sampled in years other than 1987, the average wet-weight PCB concentrations are discussed below. Average PCB concentration in channel catfish ranged from 2.53 mg/kg in 1999 to 6.36 mg/kg in 1987. Average PCB concentration in largemouth bass ranged from 0.56 mg/kg in 1985 to 1.33 mg/kg in 1985. Largemouth bass have not been sampled since 1987. Northern pike averaged 1.33 mg/kg in 1987 and 0.26 mg/kg (n=4) in 1999. PCB concentration in walleye averaged 0.58 mg/kg in 1987 and 0.18 mg/kg in 1999.

4.3.14 Saugatuck Near River Mouth

Carp
Five carp were captured in 1993 near the Kalamazoo River Mouth at Lake Michigan and a single composite sample was analyzed with PCB concentration 1.09 mg/kg.

4.3.15 Portage Creek-Monarch Mill Pond

Carp
Carp were sampled from Monarch Mill Pond on Portage Creek in 2001 as part of the MDEQ long term monitoring program. PCB concentration among 11 fish ranged from 0.05- to 0.47- and averaged 0.18-mg/kg below the 0.2 mg/kg MDCH one-meal-

per-month advisory level for women and children, but above the 0.11 MDEQ risk-based cleanup goal.

4.3.16 Portage Creek-Bryant Mill Pond

Carp

Carp samples were collected from Bryant Mill Pond, on Portage Creek in 1985, 1986, 1987, 1993, 2000 and 2001. Wet-weight PCB concentration in fillets ranged from a minimum of 0.05 mg/kg in 2000 to a maximum of 27.37 mg/kg, in 1986. Average wet-weight PCB concentration ranged from 0.36 mg/kg in 2000 to 3.97 mg/kg in 1986. Average PCB concentration exceeded the 2 mg/kg MDCH general consumption advisory limit in (1985, 1986, 1987 and 1993) and exceeded the 0.2 mg/kg MDCH one-meal-per-month advisory level for women and children in 1987, 2000 and 2001. PCB contaminated paper residuals and sediment were removed from Bryant Mill Pond in 1998 and 1999, which may in part explain reduced concentrations found in 2000 and 2001.

Prior to the removal, average adjusted PCB concentration ranged from 2.01 mg/kg in 1993 to 4.65 mg/kg in 1985, exceeding the 2 mg/kg general population consumption advisory level. After the removal action, site-wide average adjusted concentrations were 0.30- and 0.44-mg/kg in 2000 and 2001 respectively, below the 2.0 mg/kg consumption advisory, but exceeding the 0.2 mg/kg MDCH one-meal-per-month for women and children after the removal action. The removal action focused on removal of PCB contaminated sediment and stream-bank restoration. These results are thought to provide direct evidence of the positive effect of contaminated sediment removal (Day, 2002).

that removal of PCB contaminated sediments contribute to reduced PCB concentration in fish tissue.

Other Species

In 2000, one 22-cm long brown trout (*Salmo, trutta*) was captured from Bryant Mill Pond after the removal action was completed in 1999. This wet-weight PCB concentration was 0.05 mg/kg. below the 0.11 mg/kg MDEQ risk based central tendency angler cleanup goal.

4.4 Spatial Trends in Fish Exposure to PCB

4.4.1 Spatial Trends

Naïve interpretation of spatial trends in wet-weight PCB concentration in carp fillets differ from those based on lipid- and length-adjusted concentration. For example, wet-weight concentration was in general higher in carp fillets from Plainwell than those from Lake Allegan (Table 1; Figure 9), although, after adjusting for covariation with length and lipid based on site-wide averages, concentrations at Plainwell Impoundment were similar to those at Lake Allegan (Table 1; figure 9). This indicates that bioaccumulation of PCB at Lake Allegan and Plainwell Impoundment may be similar and that differences in wet-weight PCB concentrations are due in part to differences in the lipid and length distributions of fish from these ABSA.

Carp

In 2001, average adjusted PCB concentration increased with distance downstream from 0.41 mg/kg at Battle Creek to 3.31 mg/kg at Trowbridge Impoundment (Figure 9). Average adjusted PCB concentration at Plainwell Impoundment (1.73 mg/kg) was similar to that at Lake Allegan (1.59 mg/kg). Average adjusted fillet PCB concentration at New Richmond (2.12 mg/kg) was similar to that at Otsego City (2.05 mg/kg) and Otsego (2.54 mg/kg) Impoundments. Average adjusted fillet PCB concentration at Saugatuck (0.83 mg/kg) was similar to that at Morrow Pond (0.74 mg/kg).

Smallmouth Bass

The relative spatial distribution of average adjusted PCB concentration in smallmouth bass in 2001 was similar to that for carp. The lowest average adjusted PCB concentration (0.03 mg/kg) occurred at Battle Creek and the highest adjusted average PCB concentration (1.04 mg/kg) occurred at Trowbridge Impoundment. Average adjusted concentrations in general increased with distance downstream from Battle Creek followed by a decline with distance downstream from Trowbridge Impoundment. Adjusted average PCB concentration was lower at Battle Creek and Morrow Pond than at any ABSA downstream of Morrow Dam.

4.5 Temporal Trends

Mean adjusted PCB concentration for carp and smallmouth bass was modeled assuming that the mean followed a mixed order model with lognormal error. Parameters were estimated by the method of maximum likelihood (Casella and Berger 1990) and are summarized in Table (4).

Three parameters are reported in Table (4) including an estimate of the percentage reduction per year in concentration $Diff = (C_{final} - C_{initial})/(\overline{C} \times \Delta t) \times 100\%$ with 95% confidence limits and the significance level for a one sided test of the null hypothesis of no decrease in concentration. This test is analogous to testing for a significant negative slope in the first order decay model. However, a reduction in PCB concentration over the monitoring period does not imply that future reductions will continue at the same decay rates.

When there is significant decay in concentration, *2* determines the shape of the decay function. The maximum likelihood estimate of *2* is included in Table (4) with 95% confidence limits. The statistical significance probability for the null hypothesis of exponential decay (i.e., H_0:*2*=0) is also reported. Deviation from exponential decay rates can also be assessed graphically by looking at the plotted models in Figures (11) through (33). The plots are in natural log scale, so when decay rates are exponential, the plotted model is linear. When the decay rate is decreasing/increasing the plotted models are concave up/down respectively.

Finally, the standard deviation of the log-normal distribution F is also reported with 95% confidence limits. Tests of significance and confidence limits for model parameters were estimated by bootstrap resampling.

Trend models were estimated for each ABSA using all available data, and data collected since 1990. For each combination of species, ABSA and data subset, the data were adjusted to represent; 1) fish with ABSA-specific-average length and lipid fraction, and 2) fish with site-wide-average length and lipid fraction. The resulting models are plotted in Figures (11) through (33). Each figure where data are available prior to 1990 contains 4 panels. Panels (A) and (B) contain models for the ABSA-specific and Site-wide adjustments respectively and are based on all available data. Panels (C) and (D) contain models for the ABSA-specific and site-wide adjustments respectively but are based on data collected from 1990 forward.

Each plot contains 4 horizontal lines; at 2.0 mg/kg representing the MDCH general consumption; 0.2 mg/kg representing MDCH one-meal-per month advisory; 0.11 mg/kg representing the MDEQ risk based cleanup goal protective of central tendency anglers; and 0.05 mg/kg representing the MDCH one meal per week criteria for women and children. The estimated mixed order model is plotted with a black line and upper and lower 95% confidence limits are plotted with blue lines. Confidence limits were estimated by bootstrap resampling. The sample mean adjusted PCB concentration is also plotted for each year with 95% bootstrap confidence limits.

In the following, trend analysis results are discussed on an ABSA basis, so trends in ABSA-specific adjusted concentrations are discussed. These models are plotted in panels (A) and (C) in the corresponding figures. Models plotted in Panels (B) and (D) are appropriate for among ABSA comparisons, although they are not discussed in detail below.

4.5.1 Battle Creek

Carp

ABSA-specific adjusted PCB concentration in carp 1986 through 2001 (Model I) and 1990 through 2001 (Model II) did not decline significantly (p>0.70). Plotted models in Figure (11) indicate that adjusted fillet PCB concentrations may be at equilibrium. It is anticipated that in the near future, PCB concentrations in carp fillets will remain similar to current levels, provided that lipid fraction and size distributions of fish remain similar.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets have declined at an average annualized rate of 9.4- to 10.4-percent per year since 1994 ($p<0.002$). Adjusted PCB concentrations in 1994 and 1997 were similar and higher than in fish sampled in 1999 through 2001 (Figure 12).

The observed decay rate was similar to exponential ($p > 0.31$) for both ABSA-specific and site-wide adjusted data.

It should be noted that the temporal record for smallmouth bass at Battle Creek is short (1994-2001) so forward projections should be viewed with caution.

4.5.2 Morrow Pond

Carp
ABSA-specific adjusted PCB concentration in carp declined at an average annualized rate of 10% (95% confidence limits: 5% to 20%) from 1986 through 2001 (Model I). Decay rates from 1993 through 2001 (Model II) were similar (10%) although 95% confidence intervals were wider (3% to 20%) due primarily to the restricted number of years analyzed. Plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential ($p=0.15$; Figure 13 panel A) indicating that decay rates may be decreasing with time. Carp fillet concentrations are currently below the 2 mg/kg MDCH general consumption advisory level and are expected to approach the 0.2 MDCH one-meal-per-month advisory level by 2010 (95% CL: 2005 to >2020: Figure 13, Panel A).

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at an average annualized rate of 16% (95% CL: 9.5% to 24%) from 1985 through 2001 (Model I). Decay rates from 1993 through 2001 (Model II) were slower (11.2%; 95% CL: 5% to 20%) Based on the full data set, plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential ($p=0.26$; Figure 14 panel A) indicating that decay rates may be decreasing with time. Smallmouth bass fillet concentrations are currently below the 0.2 mg/kg MDCH one-meal-per-month advisory level and near to the 0.11 mg/kg MDEQ risk based level necessary to protect central tendency anglers. Future projections indicate that concentration will be below this risk based level by 2007 with 95% level of confidence. Based on the 1993 through 2001 data, one would expect average concentrations to be below the risk based level before 2005.

4.5.3 Downstream of Morrow Dam

Fish samples were collected from the area below Morrow Dam in 1993 and 2000 providing just 2 points in time from which to infer temporal trends. These data are probably not adequate to make reliable forecasts of PCB concentration, nor are tests for exponential decay reliable. Nonetheless, the MO model was estimated for these data and the results are plotted on Figures (15) and (16). Adjusted average PCB concentration was lower in 2000 than in 1993 for both carp and smallmouth bass samples ($p<0.015$). Annualized decay rates were slower than at Morrow Pond, 7.9% (95% CL: 2.3% to 15.1%) for carp and 7.4% (1.0% to 13.5%) for smallmouth bass.

4.5.4 Mosel Avenue

Carp

ABSA-specific adjusted PCB concentration in carp declined at an average annualized rate of 3% (95% confidence limits: 1% to 5%) from 1983 through 2001 (Model I). Decay rates from 1993 through 2000 (Model II) were similar (4%; 95% CL: 0.3% to 9%). The best-fit model was concave-up, but the decay rate was not statistically different from exponential ($p=0.33$; Figure 17 panel A). Adjusted carp fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 2000 and may remain there beyond 2020. It is expected that PCB concentrations will remain above 0.2 mg/kg (MDCH one-meal-per month advisory) through 2020 with 95% level of confidence.

Smallmouth Bass

ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at an average annualized rate of 10% (95% CL: 3% to 17%) from 1985 through 2000 (Model I; Figure 18-A) but increased from 1993 through 2000 (Model II; Figure 18-B) at a rate of 4% (95% CL: 8% to 0%) Based on the full data set, plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential ($p=0.26$; Figure 18-A) indicating that decay rates may be decreasing with time. Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month for women and children level. Future projections based on all data indicate that concentration will be above this one-meal-per-month level through 2015 with 95% level of confidence. The 1993 through 2000 data, indicate that average concentrations may remain above the 0.2 mg/kg level indefinitely and could approach the general consumption advisory level.

4.5.5 Plainwell Impoundment

Carp

ABSA-specific adjusted PCB concentration in carp declined at an average annualized rate of 5% (95% confidence limits: 2% to 9%) from 1983 through 2001 (Model I; Figure 19-A). Decay rates from 1993 through 2001 (Model II; Figure 19-C) were similar (5%; 95% CL: -0.1% to 9%). The best-fit model was concave-up but the decay rate was similar to exponential ($p=0.24$; Figure 19-A). Adjusted carp fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 2001 and may remain there beyond 2020. It is expected that PCB concentrations will remain above 0.2 mg/kg (MDCH one-meal-per month advisory) through 2020 with 95% level of confidence.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined with an average annualized rate of 9% (95% CL: 0.8% to 17%) from 1993 through 2001. Plotted models were concave-up indicating that the decay rate for the best fit model was slower than exponential (p=0.10; Figure 20-A) indicating that decay rates may be decreasing with time. Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption advisory level but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children. Future projections based on the best fit model indicate that PCB concentration will be above this one-meal-per-month level through 2010 with 95% level of confidence and may remain there beyond 2020.

4.5.6 Otsego City Impoundment

Carp
ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 5% (p=0.06; 95% confidence limits: -1.2% to 14.7%) from 1993 through 2001 (Figure 21-A). The best-fit model was concave-up and the decay rate was slower than would be expected under the first order decay assumption(p=0.048; Figure 21-A) indicating that decay rates may be decreasing with time. Adjusted carp-fillet PCB concentrations were below the 2 mg/kg MDCH general consumption advisory level in 1999 ($p < 0.05$) and above the general consumption advisory level in 2001. Lower 95% confidence limit for adjusted concentrations is projected to remain above the 0.2 MDCH one meal-per-month advisory level through at least 2020. Upper 95% confidence limits indicate that concentrations could remain above the 2 mg/kg general consumption advisory limit beyond 2020. The best estimate for PCB concentration in 2020 is approximately 1 mg/kg (MDCH 6 meal per year advisory).

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets remained unchanged from 1993 through 2001 (p=0.40; Figure 22-A). Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children. Under current site conditions, future concentrations can be anticipated to remain similar provided that fish length and lipid-fraction distributions remain similar.

4.5.7 Otsego Impoundment

Carp
ABSA-specific adjusted PCB concentration in carp fillets did not decline (p=0.47; 95% confidence limits: -8% to 8%) from 1993 through 2001 (Figure 23-A). Adjusted carp-fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 1993, 1999 and 2001 ($p < 0.05$). Given the lack of evidence of any temporal trend in PCB concentration it is expected that under current site conditions, future concentrations will be similar to those observed over this 3 year period.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at a 7% average annualized rate from 1993 through 2001 (95% confidence limits 3.2 to 13.3; Figure 24-A). Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children and under current site conditions are projected to decline to near this level by 2020.

4.5.8 Trowbridge Impoundment

Carp
ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 8% (95% Confidence limits: 2% to 14%) from 1993 through 2001 (Figure 25-A). Decay rates were different from exponential ($p=0.13$) indicating that future decay rates are expected to decline with time. Adjusted carp-fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 1993, 1999 and 2001 ($p < 0.05$). and may continue to exceed this level through 2020. PCB concentrations are projected to remain above the 0.2mg/kg MDCH one-meal per month advisory level through 2020 with 95% confidence.

Smallmouth Bass
ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at a 7% average annualized rate (95% Confidence limits: 4% to 11%) from 1993 through 2001 ($p<0.010$; Figure 26-A). Estimated decay rates were similar to exponential. Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption advisory level, but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children. Under current site conditions concentrations are expected to remain above this level through 2012 ($p=0.025$) and are likely to exceed this level beyond 2020.

4.5.9 Lake Allegan

Carp
ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 9% (95% CL: 7% to 10%) from 1993 through 2001 (Figure 27-A). The decay rate was similar to exponential ($p=0.55$). The estimated annualized decay rate from 1993 through 2001 was similar to that based on all data (14%; 95% CL: 7% to 24%) but the decay rates was slower than exponential ($p=0.05$) indicating that decay rates may be decreasing with time.

Adjusted carp-fillet PCB concentrations were below the 2 mg/kg MDCH general consumption advisory level in 2001 ($p < 0.05$). Based on all data, adjusted PCB concentration is expected to be above the MDCH 0.2 mg/kg advisory level through approximately 2007 with 95% confidence and is expected to remain above this level through 2010.

Future projections of PCB concentrations at Lake Allegan are heavily influenced by PCB concentration in carp fillets collected in the 1980s. Average adjusted PCB concentration projections in 2020 were below the 0.11 mg/kg MDEQ risk based level when all data were considered. However, projected concentrations were greater than the 0.2 mg/kg advisory level when the model was restricted to data from 1993 through 2001.

Smallmouth Bass

ABSA-specific adjusted PCB concentration in smallmouth bass fillets declined at a 15% (95% CL: 11% to 21%) average annualized rate from 1993 through 2001 ($p<0.001$; Figure 28-A). Estimated decay rates were similar to exponential ($p=0.71$). Smallmouth bass fillet concentrations are currently below the 2.0 mg/kg MDCH general consumption but above the 0.2 mg/kg MDCH one-meal-per-month level for women and children and under current site conditions are expected to remain above this level through 2007 ($p=0.025$) and are likely to exceed this level beyond 2015.

From 1993 through 2001, adjusted PCB concentrations decayed at an 11% average annualized decay rate (95% CL: -.05 to 25%). Decay was slower than exponential ($p=0.01$) indicating that decay rates may be decreasing with time. Based on this more recent data, PCB concentrations are projected to be above the 0.2- and 0.11-mg/kg advisory levels through at least 2007 and 2012 respectively with 95% confidence. Concentrations may remain above the 0.2 mg/kg advisory level beyond 2020, based on 95% upper confidence limits.

4.5.10 New Richmond

Carp

ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 11% (95% CL: 0.7% to 25%) from 1993 through 2001 (Figure 29-A). The decay rate was slower than expected for exponential decay ($p=0.07$) indicating that decay rates may be decreasing with time.

Adjusted carp-fillet PCB concentrations were above the 2 mg/kg MDCH general consumption advisory level in 2001 ($p < 0.05$). Adjusted PCB concentration is expected to be above the MDCH 0.2 mg/kg advisory level through approximately 2015 with 95% confidence and may remain above this level through 2010. Upper 95% confidence limits indicate that PCB concentration may exceed 2 mg/kg beyond 2020.

Smallmouth Bass

ABSA-specific adjusted PCB concentration in smallmouth bass fillets did not decline from 1993 through 2001 ($p=0.74$; Figure 30-A) and may be increasing. Concentrations are expected to remain below 2 mg/kg and above 0.2 mg/kg through 2020.

4.5.11 Saugatuck

Carp

ABSA-specific adjusted PCB concentration in carp fillets declined at an average annualized rate of 7.5% (95% CL: 4.0% to 10.0%) from 1983 through 2001 (Figure 31-A). The decay rate was similar to exponential decay ($p=0.44$).

Adjusted fillet PCB concentrations were above the 0.2 mg/kg MDCH general consumption advisory level in 2001 ($p < 0.05$). Adjusted PCB concentration is expected to remain above the MDCH 0.2 mg/kg advisory level through approximately 2010 with 95% confidence and may remain above this level beyond 2020. Upper 95% confidence limits indicate that PCB concentration may exceed 2 mg/kg through 2015.

Smallmouth Bass

Smallmouth bass were collected in 1997 and 2001 only. The MO model was fit to the data, but estimated temporal trends may not be reliable (Figure 32).

4.6 Comparison With Other Sites

Whole body carp from Lake Allegan had significantly higher PCB concentrations than those from 3 of the 4 inland sites, (Raisin, Grand and Muskegon Rivers) and 3 of the 7 great lakes sites (Lake St. Clair, Munuscong Bay, Thunder Bay; $p<0.05$). Whole-body carp from the St. Joe River had lower PCB concentrations than those at Lake Allegan, although differences were not statistically significant at the 0.05 level (Figure 33). PCB concentrations in whole-body carp from Lake Allegan were similar to those at Lake Erie, Grand Traverse Bay, the Detroit River, Saginaw Bay and the St. Joe River.

After adjusting for variation in length and lipid-content, geometric mean PCB concentration in whole-body carp from Lake Allegan (4.75 mg/kg) was exceeded only by that from Lake Erie (6.1 mg/kg). PCB concentrations in whole-body carp at Lake Allegan were similar to those from the remaining great lakes sites where lipid- and length-adjusted geometric mean PCB concentrations ranged from 0.5- to 6.1 mg/kg.

With the exception of Lake Allegan and the St. Joe River, PCB concentrations in whole-body carp from inland-river sites were generally lower than those from great-lakes and connecting waters sites. One notable exception was at Munuscong Bay along the St. Maries River which connects Lakes Superior and Huron. Munuscong Bay had the second lowest geometric mean concentrations (GM=0.25 mg/kg) among all sites. The only site with lower adjusted PCB concentrations was the Muskegon River (GM=0.02 mg/kg).

Section 5
Fish Consumption Advisories

5.1 Consumption Advisory Criteria

The MDCH has two distinct sets of criteria for what is termed the general population as opposed to women of child bearing age and children. These criteria are spelled out in sections 5.1.1 and 5.1.2. MDCH compares wet-weight total PCB concentration to the criteria without regard to lipid distributions. Attempts are made to control for fish size and age by limiting the size distribution of fish retained for analysis. Wet-weight PCB concentration in carp and smallmouth bass fillets collected from 1998 through 2001 were compared with these criteria and summarized in Table (6). Because the MDCH and MDEQ consider other factors when setting fish advisories on waters of the state, these results should not be considered as an endorsement to consume fish from the Kalamazoo River, nor are they a recommendation to the MDCH/MDEQ for setting consumption advisories.

5.1.1 General Population

For the general population, PCB concentrations are compared to the 2.0 mg/kg level. When 50% or more of samples have concentration greater than 2.0 mg/kg a no consumption advisory would be put in place. When 11% to 49% of samples are greater than 2.0 mg/kg a one meal per week limit is recommended. When less than 11% of samples are below the MDCH criteria, unlimited consumption is permitted.

5.1.2 Women of Child Bearing Age and Children

Fish consumption advisories for women of child bearing age and children less than 15 years of age are based on average concentration rather than sample percentages. A no-consumption advisory is recommended when average concentration is greater than 1.9 mg/kg. When average concentration is between 1.0- and 1.9-mg/kg no more than 6 meals per year are recommended. When average concentration is between 0.2- and 1.0-mg/kg no more than one-meal-per-month is recommended. When average concentration is between 0.05- and 0.2-mg/kg no more than one meal per week is recommended, and when average concentration is below 0.05 mg/kg, unlimited consumption is permitted.

5.2 Comparison of Fillet data to Advisory Criteria

Wet-weight Total PCB concentrations for carp and smallmouth bass collected from 1998 through 2001 were compared to MDCH fish consumption criteria as described in sections 5.1.1 and 5.1.2. The results of these comparisons are summarized in Table (6).

5.2.1 Smallmouth Bass

If advisories were based solely on these criteria applied to fillets collected in 1999, 2000 and 20001, unlimited consumption of smallmouth bass could currently be permitted at all sites for the general population, but only at Battle Creek for women and children. No more than one meal per week would be permitted at Morrow Pond and no more than one-meal-per-month could be permitted at the remaining sites excluding Trowbridge Impoundment where women and children would be limited to six meals per year.

5.2.2 Carp

For carp, unlimited consumption would only be permitted for the general population at Battle Creek, Morrow Pond, Monarch Mill Pond, each of which are upstream of the superfund site, and former Bryant Mill Pond where the removal action took place in 1998-99. No consumption would be advised from Morrow Dam to Plainwell Dam, Otsego Impoundment, Trowbridge Impoundment and Allegan City Impoundment. No more than one meal per week would be advised at the remaining areas, Otsego City Impoundment, Lake Allegan and Lake Allegan Dam to Lake Michigan.

For women and children, no consumption would be advised at all areas from Morrow Dam downstream to Allegan City Dam and from Lake Allegan Dam downstream to Lake Michigan. No more than six meals per year would be advised from Lake Allegan. No more than one-meal-per-month would be advised for Battle Creek, Morrow Pond and Bryant Mill Pond, and no more than one meal per week would be advised from Monarch Mill Pond.

Section 6
Findings and Conclusions

6.1 General Findings

The distribution of fish length and lipid fraction varied both spatially and temporally and explained a significant proportion of variation in fillet PCB concentration in both carp and smallmouth bass. Failure to adjust wet-weight PCB concentration for covariation with length and lipid may result in erroneous interpretations of PCB trends. We adjusted wet-weight PCB concentration in two ways; (1) based on within ABSA average of length and lipid, and (2) based on the overall site-wide average of length and lipid.

Within-ABSA adjusted data are representative of long-term exposures that fish consumers could expect from fish from a particular ABSA. Differences among these ABSA-specific adjusted concentrations could be due to differences in fish exposures to PCB, differences in lipid and length distributions or both. Fish exposures to PCBs can in turn be influenced by PCB concentration in sediment, water and prey, as well as other factors such as longevity, behavior, and species specific physiology. Alternatively, PCB concentration adjusted to length and lipid distributions representing site-wide averages can be interpreted as an indicator of site conditions after controlling variations in lipid and length. Among ABSA differences in site-wide adjusted concentrations indicate differences in site conditions controlling fish bioaccumulation of PCB.

6.1.1 Study Limitations

Full understanding and correct interpretation of any scientific data should include a discussion of potential limitations of the study design and or implementation. In this study, fish fillet data were generated by multiple scientific teams with varying objectives and field sampling and handling methods. Temporal variation may be confounded with field technicians, laboratories and analytical methods,although we found no evidence of systematic bias. Additionally, forward projections of tissue PCB concentrations are based on the assumption that fitted models are appropriate. For any model based analysis statistical inferences and confidence limits for temporal forecasts are conditional on the class of allowable models—in this case the mixed order and exponential decay models. Verification of findings of this study will require continued monitoring of PCB concentrations in carp and smallmouth bass fillets maintaining consistent field methods and laboratory standard operating procedures.

6.2 Fillet PCB as an Indicator of Site Conditions

Adjusted PCB concentration based on site-wide adjustments is a general indicator of fish bioaccumulation of PCB. Since the early to mid 1980s, fish bioaccumulation of PCB contamination at most ABSA has declined. The rate of these declines varies with species, location and time. For example at Mosel Avenue from 1990 through 2001, adjusted PCB concentration in carp fillets dropped at an annualized rate of 4% while adjusted concentrations in smallmouth bass fillets remained essentially unchanged or may have increased. Conversely, at Battle Creek, adjusted PCB concentrations in carp fillets were unchanged from 1987 through 2001, while concentrations in smallmouth Bass were declining at a 9- to 10% annualized rate. PCB concentrations in smallmouth bass at Mosel Avenue have apparently not changed since 1993. At Plainwell Impoundment, PCB concentration declines in carp fillets have slowed from a 5.8% average annualized rate from 1983 through 2001, to a 4.6% rate in the 1990s through 2001. While these changes in decay rate are fairly small, they may translate into fairly large differences in the time required to attain remedial objectives. Assuming that PCB concentration will decay exponentially in the future may result in overly optimistic projections of the performance of natural attenuation as a remedial alternative.

In general, after controlling for variations in lipid and length distributions, fish within the superfund site are exposed to and have accumulated higher PCB concentrations than those upstream of the site (Battle Creek, Morrow Pond; Figure 9). For carp, exposure to PCB increases with distance downstream from Morrow Pond with a maximum at Trowbridge Impoundment. Carp exposures to PCB at Lake Allegan, New Richmond and Saugatuck are lower than at Trowbridge, but similar to Plainwell and Otsego City Impoundments. It is interesting to note that wet-weight concentrations at Plainwell are much higher than at Lake Allegan, while after controlling for length and lipid variation fillet concentrations are similar.

6.3 Exposure of Fish Consumers to PCB

Fillet PCB concentration adjusted to ABSA-specific average length and lipid levels are an indicator of the expected long-term exposure that fish consumers could expect from eating fish from a particular ABSA. These adjusted data incorporate the exposures that fish are receiving as well as accounting for differences in the historic distribution of length and lipid among ABSA. For example, since the 1980s carp collected form Lake Allegan have historically been smaller and have had lower lipid levels than at Plainwell Impoundment. So, although carp are exposed to similar concentrations of environmental PCB at both ABSA, fish consumers could expect higher long-term exposures of PCB from Plainwell Impoundment than from Lake Allegan because fish consumers can expect to catch larger carp with higher lipid levels at Plainwell.

In 2001, fish consumers could expect an average exposure of 2- to 4- mg/kg wet-weight PCB from carp fillets at Plainwell, Otsego City, Otsego and Trowbridge and Allegan City Impoundments and in the Kalamazoo river near New Richmond (Table 1; Figure 9). These concentrations are at levels that would trigger MDCH no-consumption advisories for all potential consumers

The expected average exposures at Lake Allegan and Saugatuck were somewhat lower, (0.7- and 1.2-mg/kg respectively) but at levels that would trigger some form of consumption advisory. All concentrations were greater than the MDCH risk based cleanup goal protective of central tendency sport anglers.

PCB concentrations in fish tissues are a function of concentration in water, sediment and prey, lipid content and exposure duration, indexed by age or length. Although current PCB concentrations in Lake Allegan carp are lower than at surrounding ABSA (New Richmond and Allegan city Dam) this is primarily due to differences in lipid and length distributions. If changes in environmental conditions or fisheries management practices were to induce an increase in the lipid fraction in carp at Lake Allegan, PCB concentrations would be expected to increase to levels similar to those at other ABSA within the superfund site.

Estimated long-term exposure to PCB for consumers of smallmouth bass in 2001 was lower than that for consumers of carp. Long-term exposures at ABSA within the superfund site in 2001 are estimated to range from 0.5- to 1-mg/kg, while those at Battle Creek and Morrow Pond are estimated to be approximately 0.03- and 0.09-mg/kg respectively (Table 1 and Figure 9).

With the exception of Lake Allegan, PCB concentration in carp fillets from ABSA within the superfund site are expected to range from approximately 0.6- to 3.0-mg/kg in 2020 (Figure 34). These predictions are precise to approximately one order of magnitude. The difference between no-consumption and limited-consumption criteria is approximately one order of magnitude, so it is difficult to predict whether consumption advisory limits for carp would be lifted by 2020. Average PCB concentrations in carp fillets at Lake Allegan are expected to range from less than 0.01 to approximately 0.3 mg/kg.

Under existing conditions, PCB concentrations in smallmouth bass fillets from ABSA within the superfund site are expected to range from approximately 0.1- to 1.0 mg/kg in 2020. As with PCB concentrations in carp fillets, PCB concentrations in smallmouth bass fillets at Lake Allegan are expected to be lower than at other ABSA, ranging from 0.006- to 0.2-mg/kg.

These predictions are based on the assumption that the MO is appropriate for evaluating these data. At most ABSAs, the MO and first order decay models fit the data equally well. At some ABSAs we reject the hypothesis of exponential decay. For the most part, the decay rate of the best MO declined with time, but differences from exponential decay were not statistically significant. This suggests that PCB decay rates in carp and smallmouth bass fillets cannot be expected to continue at rates observed in the 1980s and early 1990s. In general, existing data are not adequate to precisely determine the rate at which PCB concentrations will decay in the near future. The rapid decay rates observed from the early 1980s to 1990 tend to dominate estimates of future decay rates. More recent data suggest that decay rates are beginning to slow, although the currently available temporal record is not adequate to precisely estimate the degree to which decay rates may be changing.

Based on the existing data it is likely that, at most ABSA, some form of consumption advisory will continue through 2020 for carp. In particular, concentrations are most likely to remain elevated at Plainwell, Otsego City, Otsego, Trowbridge and Allegan City Impoundments.

6.4 Comparison of Wet-weight PCB Concentrations to Advisory Criteria

Wet-weight PCB concentrations in carp from throughout the superfund site are at levels that would trigger some form of consumption advisory. At the three former impoundments (Plainwell, Otsego and Trowbridge) wet-weight PCB concentrations are at levels that would trigger a no-consumption advisory.

Upstream of the superfund site, (Battle Creek, Morrow Pond and Monarch Mill Pond) PCB concentrations are at levels where the general population could be permitted unlimited consumption. At these same sites, wet-weight concentrations are such that women and children would be restricted to one-meal-per-month with the exception of Monarch Mill Pond where women and children could eat one meal per week.

At all ABSA including those up stream of the superfund site, wet-weight PCB concentrations in carp fillets are above the risk-based 0.11 mg/kg MDEQ cleanup goal protective of central tendency sport anglers. Wet-weight PCB concentration in smallmouth bass fillets in 1999, 2000 and 2001 are sufficiently low that general-population consumption advisories would not be triggered at any ABSA.

For women and children, unlimited consumption of smallmouth bass fillets could be permitted at Battle Creek, but some form of advisory would be triggered at all other ABSA. At all sites except Battle Creek, Average Wet-weight PCB concentration in smallmouth bass were higher than the risk-based 0.11 mg/kg MDEQ cleanup goal designed to be protective of central tendency sport anglers.

6.5 Interim Removal Action at Former Bryant Mill Pond

There has been considerable debate about the potential for environmental dredging to produce short- or even long-term reductions in fish tissue contaminant concentrations (General Electric 2000). However, the majority of sediment removal actions cited by General Electric involved removal of localized hot-spots which may have only minimally impacted the overall average concentrations to which biota are exposed. However, a remedial action conducted in Sweden, (Gullbring et al. 1998) included dredging of expansive areas of Lake Jarnsjon resulting in post remedial average sediment concentrations below 1.0 mg/kg. At this site, follow-up studies of fish tissue concentrations (Bremle, 1998) indicated that PCB concentrations had declined in the first year after the remediation, although reductions could not be separated from that expected through natural attenuation.

At Former Bryant Mill Pond on Portage Creek, a similar approach was taken in that nearly all PCB containing sediments were removed from the currently and formerly impounded areas area rather than attempting to isolate and remove individual hotspots. Carp were sampled both before and after the removal action, and post removal concentrations are substantially lower than would have been expected under natural attenuation (Figure 35). Under a no action alternative, concentrations at Bryant Mill Pond are predicted to have been around 1.0 mg/kg in 2020. In 2000 and 2001, after the removal action, Carp fillet concentrations averaged 0.3 mg/kg and 0.4 mg/kg respectively. This suggests that the removal action may have accelerated recovery by over 20 years relative to natural attenuation. These data support the hypothesis that environmental dredging can be successful when contaminant deposits are properly delineated and a conservative approach is used to identify and remove potentially contaminated sediments.

Section 7
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Tables

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg) Site-wide		Adjusted[1,2] PCB (mg/kg) ABSA-specific		Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
				Min	Max	Avg.	Model I[4]	Model II	Model I	Model II				
BATTLE CREEK														
CARP	MICH	1987	9	0.03	0.24	0.12	0.10		0.09		52.0	1736	2.47	1.18
	MICH	1991	5	0.03	0.73	0.27	0.90	0.90	0.67	0.63	55.8	2260	0.93	1.30
	BBL	1993	11	0.06	0.17	0.08	0.10	0.10	0.09	0.09	56.8	2872	1.22	1.56
	BBL	1997	11	0.04	0.27	0.09	0.23	0.23	0.19	0.19	55.6	2491	0.75	1.44
	LTM	1999	11	0.04	0.29	0.09	0.07	0.07	0.06	0.06	56.0	2624	2.62	1.46
	LTM	2000	11	0.06	0.38	0.20	0.13	0.13	0.11	0.10	57.5	2966	3.07	1.55
	LTM	2001	11	0.06	1.17	0.40	0.41	0.41	0.41	0.42	59.1	3082	3.28	1.49
LARGEMOUTH BASS	MICH	1987	1	0.02	0.02	0.02					36.5	700	0.60	1.44
SMALLMOUTH BASS	MICH	1987	1	0.04	0.04	0.04					38.0	650	0.50	1.18
	MICH	1991	4	0.03	0.18	0.09					29.5	310	0.83	1.21
	BBL	1993	11	0.05	0.31	0.13	0.06	0.06	0.05	0.05	36.5	1124	1.41	2.29
	BBL	1997	11	0.03	0.08	0.05	0.05	0.05	0.05	0.05	38.3	891	0.50	1.57
	LTM	1999	11	0.03	0.04	0.03	0.03	0.03	0.03	0.03	30.2	397	0.70	1.34
	LTM	2000	11	0.05	0.06	0.05	0.03	0.03	0.03	0.03	30.6	464	0.36	1.55
	LTM	2001	11	0.05	0.08	0.06	0.03	0.03	0.03	0.03	34.0	657	0.94	1.46

Note: See footnotes on page 17

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Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
MORROW POND														
CARP	MICH	1985	20	0.39	8.90	2.54	2.91		1.77		47.9	1481	1.61	1.34
	MICH	1986	20	0.60	12.69	3.46	4.67		3.33		46.9	1398	2.43	1.35
	MICH	1987	9	0.26	5.83	1.42	1.94		1.14		50.6	1589	1.33	1.22
	BBL	1993	11	0.08	1.90	0.61	0.93	1.12	0.59	0.55	62.0	3917	1.06	1.50
	BBL	1997	11	0.06	0.65	0.26	0.76	0.88	0.48	0.45	59.5	2982	0.44	1.33
	BBL	1999	11	0.17	1.04	0.49	0.60	0.64	0.39	0.39	59.4	3195	1.27	1.35
	LTM	1999	11	0.08	0.56	0.22	0.39	0.42	0.25	0.25	50.1	1515	1.10	1.17
	LTM	2001	11	0.16	2.00	0.73	0.74	0.75	0.44	0.29	54.9	2348	2.32	1.31
CHANNEL CATFISH	LTM	2001	1	0.34	0.34	0.34					54.7	1701	3.83	1.04
LARGEMOUTH BASS	MICH	1985	3	1.16	1.95	1.55					31.5	433	1.13	1.35
SMALLMOUTH BASS	MICH	1985	4	0.79	1.44	1.07	1.23		1.17		26.9	258	0.60	1.22
	MICH	1987	10	0.54	1.25	0.82	0.34		0.32		31.9	654	2.41	2.00
	BBL	1993	11	0.10	0.67	0.28	0.25	0.25	0.23	0.20	34.7	774	0.86	1.75
	BBL	1997	11	0.03	0.34	0.11	0.15	0.15	0.14	0.12	35.8	676	0.40	1.41
	BBL	1999	11	0.04	1.08	0.23	0.19	0.19	0.18	0.15	38.9	834	0.84	1.43
	LTM	1999	11	0.08	0.26	0.16	0.17	0.17	0.16	0.14	29.4	317	0.66	1.21
	LTM	2001	11	0.05	0.15	0.07	0.09	0.09	0.09	0.07	29.2	338	0.32	1.30

Note: See footnotes on page 17

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Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Model II	ABSA-specific Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
DOWNSTREAM OF MORROW DAM														
CARP	BBL	1993	11	1.40	8.20	4.43	3.52	3.52	4.69	4.69	56.1	2989	3.54	1.65
	LTM	2000	6	1.30	6.21	2.98	1.78	1.78	2.38	2.38	55.4	2348	5.14	1.31
NORTHERN PIKE	LTM	2000	1	0.43	0.43	0.43					64.6	1474	0.33	0.55
ROCK BASS	LTM	2000	1	0.05	0.05	0.05					21.5	227	0.35	2.28
SMALLMOUTH BASS	BBL	1993	11	0.38	3.23	1.09	0.63	0.63	0.61	0.61	33.4	644	1.27	1.69
	LTM	2000	11	0.06	0.57	0.28	0.41	0.41	0.39	0.39	29.5	309	0.47	1.16
	LTM	2001	1	0.56	0.56	0.56					29.7	312	0.64	1.19

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Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
MOSEL AVENUE														
CARP	MICH	1983	11	0.98	6.53	3.15	2.89		3.80		46.9	1909	2.32	1.80
	MICH	1985	18	1.42	10.80	5.08	5.72		6.52		46.2	1675	2.00	1.68
	MICH	1986	20	1.48	11.09	4.68	3.23		3.99		46.7	1890	4.11	1.83
	BBL	1993	11	1.17	12.60	6.55	2.95	3.21	3.95	6.71	58.8	3706	6.10	1.78
	BBL	1999	11	2.23	21.70	6.48	1.40	2.57	2.17	5.38	59.2	3377	7.47	1.56
	LTM	2000	5	1.25	10.34	7.76	3.01	2.58	3.70	5.38	76.3	6311	13.83	1.42
PUMPKINSEED SUNFISH	BBL	1999	11	0.18	0.60	0.35					16.7	115	1.10	2.42
SMALLMOUTH BASS	MICH	1985	2	0.90	1.89	1.40	3.48		3.76		34.1	590	0.18	1.42
	BBL	1993	11	0.16	0.72	0.48	0.46	0.46	0.49	0.53	33.4	607	0.80	1.60
	BBL	1999	11	0.36	0.95	0.67	0.58	0.59	0.63	0.67	38.2	726	0.86	1.25
	LTM	2000	11	0.20	2.35	0.87	0.63	0.63	0.68	0.72	31.3	343	1.16	1.08

Note: See footnotes on page 17

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SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
PLAINWELL DAM														
CARP	MICH	1983	11	0.88	15.90	5.47	5.02		8.24		50.6	1884	2.81	1.42
	MICH	1985	20	1.57	12.50	5.24	6.54		9.15		46.2	1416	2.40	1.44
	MICH	1986	21	0.50	9.46	4.13	4.49		6.27		47.0	1609	2.76	1.53
	MICH	1987	9	1.23	17.12	5.19	2.72		5.04		51.4	2331	4.52	1.67
	BBL	1993	11	1.44	17.20	5.81	2.28	2.47	3.96	8.88	56.5	3143	5.22	1.71
	BBL	1997	11	1.12	17.34	5.93	1.94	1.71	3.14	6.14	61.0	3700	5.69	1.51
	BBL	1999	11	5.05	16.45	9.93	2.69	1.84	4.00	6.63	67.9	4841	11.49	1.53
	LTM	1999	11	1.26	21.54	10.30	2.39	1.62	3.56	5.82	67.9	5479	11.71	1.67
	LTM	2001	11	1.36	20.65	9.80	1.73	1.74	3.01	6.26	67.8	4920	8.83	1.50
SMALLMOUTH BASS	MICH	1985	1	3.28	3.28	3.28					27.4	220	1.20	1.07
	BBL	1993	11	0.68	3.89	1.78	1.31	1.31	1.11	1.11	34.5	761	1.17	1.77
	BBL	1997	11	0.09	1.42	0.46	0.26	0.26	0.23	0.23	36.7	649	0.26	1.30
	BBL	1999	11	0.17	1.13	0.49	0.83	0.83	0.70	0.70	38.8	680	0.37	1.14
	LTM	1999	11	0.35	1.05	0.72	0.68	0.68	0.58	0.58	28.7	263	0.67	1.07
	LTM	2001	11	0.27	1.15	0.56	0.59	0.59	0.50	0.50	29.1	322	0.81	1.22

Note: See footnotes on page 17

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SUMMARY OF FILLET DATA

				Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)							
							Site-wide		ABSA-specific					
Species	Source[3]	Year	N	Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
OTSEGO CITY DAM														
BLUEGILL SUNFISH	BBL	1999	11	0.05	0.78	0.28					17.4	108	0.75	1.94
CARP	BBL	1993	11	1.05	8.03	3.44	2.75	2.75	3.00	3.00	56.1	3025	2.86	1.70
	LTM	1999	11	0.49	2.68	1.11	1.12	1.12	1.22	1.22	47.9	1513	2.31	1.37
	LTM	2001	11	0.30	7.62	2.84	2.05	2.05	2.24	2.24	56.4	2974	2.26	1.53
CHANNEL CATFISH	BBL	1999	2	4.74	5.40	5.07					63.5	2625	3.50	1.03
NORTHERN PIKE	BBL	1999	2	0.06	0.84	0.45					65.6	2260	0.55	0.73
SMALLMOUTH BASS	BBL	1993	11	0.27	3.66	0.99	1.07	1.07	1.08	1.08	34.6	837	1.56	1.96
	LTM	1999	11	0.13	1.47	0.52	0.47	0.47	0.48	0.48	32.1	457	0.65	1.24
	BBL	1999	11	0.16	2.47	1.04	1.11	1.11	1.12	1.12	40.0	868	0.91	1.27
	LTM	2001	11	0.05	1.24	0.46	1.02	1.02	0.98	0.98	28.9	405	0.42	1.69
WALLEYE	BBL	1999	1	0.89	0.89	0.89					60.6	1950	0.70	0.88

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Wet Weight PCB (mg/kg) Max	Wet Weight PCB (mg/kg) Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Adjusted[1,2] PCB (mg/kg) Site-wide Model II	Adjusted[1,2] PCB (mg/kg) ABSA-specific Model I	Adjusted[1,2] PCB (mg/kg) ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] $10,000xg/cm^3$
OTSEGO DAM														
CARP	BBL	1993	11	0.56	6.40	2.69	2.61	2.61	3.66	3.66	55.1	2874	2.33	1.65
	LTM	1999	11	0.29	4.86	2.54	1.69	1.69	2.37	2.37	55.7	2399	2.93	1.36
	LTM	2001	11	1.40	49.54	9.00	2.54	2.54	3.56	3.56	58.9	2809	5.38	1.29
SMALLMOUTH BASS	BBL	1993	11	0.39	3.73	1.48	1.24	1.24	1.03	1.03	36.4	853	0.86	1.69
	LTM	1999	11	0.31	1.15	0.58	0.59	0.59	0.58	0.58	33.6	482	0.48	1.19
	LTM	2001	11	0.32	1.09	0.63	0.60	0.60	0.62	0.62	31.2	374	0.58	1.17

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
TROWBRIDGE DAM														
BLUEGILL SUNFISH	BBL	1999	11	0.07	0.55	0.31					17.9	113	0.59	1.97
CARP	BBL	1993	11	1.31	9.60	4.55	5.13	5.13	4.82	4.82	58.2	3042	1.63	1.52
	BBL	1999	11	0.64	5.15	2.68	3.03	3.03	2.85	2.85	57.0	2836	4.92	1.43
	LTM	1999	11	0.93	16.01	3.66	3.25	3.25	3.05	3.05	51.2	1977	2.07	1.35
	LTM	2001	11	1.18	7.26	3.99	3.31	3.31	3.10	3.10	51.7	1959	2.84	1.39
CHANNEL CATFISH	BBL	1999	3	1.53	2.18	1.80					58.5	2167	3.53	1.05
	LTM	1999	1	5.09	5.09	5.09					65.1	2863	5.70	1.04
NORTHERN PIKE	BBL	1999	2	1.02	1.41	1.22					79.8	4000	0.65	0.66
SMALLMOUTH BASS	BBL	1993	11	0.74	4.19	1.95	1.68	1.68	1.59	1.59	33.5	618	0.88	1.61
	BBL	1999	11	0.39	1.42	0.73	0.96	0.96	0.91	0.91	37.6	651	0.50	1.20
	LTM	1999	11	0.47	1.63	1.14	1.15	1.15	1.09	1.09	34.2	510	0.70	1.18
	LTM	2001	11	0.60	2.77	1.15	1.04	1.04	0.99	0.99	33.9	573	0.79	1.31
WALLEYE	BBL	1999	1	0.64	0.64	0.64					50.5	1200	0.80	0.93

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)				Length	Weight	Lipid	Condition[5]
							Site-wide		ABSA-specific					
				Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	(cm)	(g)	%	10,000xg/cm[3]
CITY OF ALLEGAN DAM														
CARP	LTM	1999	11	0.43	7.25	3.34					55.8	2518	3.85	1.39
	LTM	2001	11	0.95	6.41	3.96					53.3	2142	3.81	1.39
SMALLMOUTH BASS	LTM	1999	11	0.14	0.93	0.56					29.7	392	0.50	2.37
	LTM	2001	11	0.17	0.89	0.52					31.3	430	0.62	1.34

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)				Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
							Site-wide		ABSA-specific					
				Min	Max	Avg.	Model I[4]	Model II	Model I	Model II				
LAKE ALLEGAN														
BLACK CRAPPIE	BBL	1999	1	1.16	1.16	1.16					23.1	172	1.80	1.40
	LTM	2000	1	0.40	0.40	0.40					28.0	454	0.57	2.07
BLUEGILL SUNFISH	BBL	1999	8	0.20	0.70	0.39					17.2	104	0.68	1.98
CARP	MICH	1983	3	1.60	5.03	2.77					44.5	1134	0.80	1.28
	MICH	1985	19	1.53	14.00	4.43	7.38		3.05		41.5	1043	1.59	1.45
	MICH	1986	81	0.09	23.95	4.27	12.54		3.72		38.9	850	1.18	1.31
	MICH	1987	10	1.21	6.14	3.18	9.40		3.32		40.1	864	1.04	1.33
	MICH	1990	10	1.36	5.87	3.73	6.32	6.16	2.94	3.25	39.5	868	1.67	1.41
	MICH	1992	9	0.20	7.72	4.02	6.92	6.77	1.83	1.99	41.4	1026	1.74	1.44
	BBL	1993	11	0.10	6.50	1.77	3.28	3.24	1.18	1.31	46.2	1541	1.35	1.57
	MICH	1994	10	0.57	6.50	1.84	7.16	6.98	2.16	2.36	40.2	919	0.92	1.41
	BBL	1997	11	0.26	1.65	0.72	2.00	1.99	0.97	1.09	48.1	1418	0.55	1.26
	BBL	1999	11	0.29	5.62	1.74	1.72	1.74	1.09	1.27	56.6	2427	1.00	1.26
	LTM	1999	11	0.21	1.30	0.69	0.85	0.85	0.54	0.62	47.9	1660	1.42	1.30
	LTM	2000	11	0.05	4.28	0.98	5.96	5.92	1.19	1.30	46.6	1278	0.88	1.26
	LTM	2001	11	0.49	2.92	1.49	1.59	1.59	0.73	0.83	51.7	2026	1.86	1.34
CHANNEL CATFISH	BBL	1999	11	0.24	2.87	1.09					39.2	537	1.19	0.87
	LTM	1999	1	0.55	0.55	0.55					41.5	510	1.20	0.71
	LTM	2001	6	0.61	3.77	2.17					39.7	591	1.45	0.91
LARGEMOUTH BASS	MICH	1983	2	0.39	0.44	0.42					40.0	1000		1.56
	MICH	1985	7	0.67	6.54	3.09					33.7	533	1.07	1.37

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
LAKE ALLEGAN														
LARGEMOUTH BASS	LTM	2000	1	0.31	0.31	0.31					44.0	1304	0.36	1.53
NORTHERN PIKE	MICH	1987	3	1.71	3.09	2.36					79.7	3167	0.67	0.63
	BBL	1999	11	0.32	4.60	1.81					78.9	3342	1.05	0.65
PUMPKINSEED SUNFISH	BBL	1999	3	0.27	0.55	0.41					16.1	85	0.67	2.04
SMALLMOUTH BASS	MICH	1985	3	1.90	2.42	2.12	1.95		1.94		33.1	550	0.50	1.45
	MICH	1987	10	1.39	5.14	3.05	2.09		2.16		37.6	1106	1.07	2.02
	BBL	1993	11	1.58	5.80	3.29	1.15	1.15	1.18	1.16	36.0	998	2.92	2.02
	BBL	1997	11	0.16	1.58	0.49	0.56	0.56	0.56	0.56	37.0	656	0.49	1.28
	BBL	1999	10	0.15	0.89	0.56	0.57	0.57	0.57	0.57	31.9	414	0.67	1.24
	LTM	1999	11	0.33	0.83	0.55	0.54	0.54	0.54	0.54	29.2	304	0.90	1.19
	LTM	2000	10	0.10	0.80	0.35	0.50	0.50	0.51	0.50	28.9	315	0.50	1.26
	LTM	2001	11	0.15	0.84	0.49	0.58	0.58	0.61	0.59	28.1	289	0.59	1.30
SUNFISH	MICH	1983	1	0.48	0.48	0.48					19.7	153		2.00
WALLEYE	BBL	1999	11	0.18	1.53	0.76					45.9	1002	0.92	0.99
	LTM	2000	2	0.32	1.80	1.06					51.7	1871	1.20	1.52

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Model II	ABSA-specific Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
DOWNSTREAM OF ALLEGAN DAM														
CARP	BBL	1993	11	1.93	17.00	7.60					62.5	5861	10.38	2.01
SMALLMOUTH BASS	BBL	1993	11	1.05	2.42	1.89					35.7	962	1.77	2.03

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
NEW RICHMOND														
CARP	BBL	1993	11	1.39	9.10	4.95	7.45	7.45	5.90	5.90	58.7	4348	8.14	1.90
	BBL	1997	12	0.36	17.30	4.72	1.95	1.95	3.28	3.28	57.7	3183	6.45	1.56
	BBL	1999	11	1.97	6.87	3.53	1.93	1.93	2.94	2.94	60.9	3575	5.62	1.46
	LTM	1999	10	0.20	4.06	1.58	1.17	1.17	1.78	1.78	54.6	2517	4.85	1.37
	LTM	2001	11	0.48	5.80	2.34	2.12	2.12	3.60	3.60	51.2	1799	2.40	1.32
CHANNEL CATFISH	BBL	1999	1	1.61	1.61	1.61					34.1	355	4.50	0.90
	LTM	1999	1	1.70	1.70	1.70					56.7	1474	2.35	0.81
FLATHEAD CATFISH	LTM	2001	4	0.60	3.32	1.96					74.6	5209	0.98	1.14
LARGEMOUTH BASS	LTM	1999	2	0.81	1.09	0.95					37.3	794	1.03	1.43
NORTHERN PIKE	BBL	1999	4	0.33	0.46	0.39					67.5	1818	0.53	0.58
SMALLMOUTH BASS	BBL	1993	11	0.13	0.83	0.54	0.49	0.49	0.49	0.49	29.5	538	0.87	1.85
	BBL	1997	11	0.20	4.30	1.07	1.25	1.25	1.25	1.25	37.8	859	0.52	1.57
	BBL	1999	11	0.05	2.72	0.73	0.77	0.77	0.77	0.77	34.2	484	0.81	1.15
	LTM	1999	7	0.31	1.45	0.67	0.52	0.52	0.52	0.52	33.7	571	1.25	1.29
	LTM	2001	10	0.28	0.89	0.59	0.60	0.60	0.60	0.60	30.5	403	0.67	1.36
WALLEYE	BBL	1999	11	0.03	0.92	0.28					47.8	1212	1.44	1.01

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
SAUGATUCK														
BLACK CRAPPIE	MICH	1987	10	0.30	1.59	0.70					26.0	315	0.82	1.73
BLUEGILL	MICH	1987	10	0.19	0.68	0.43					18.3	169	1.08	2.72
BROWN TROUT	MICH	1987	4	1.32	4.62	3.73					52.1	1855	9.33	1.31
	LTM	1999	1	0.90	0.90	0.90					60.0	2466	6.55	1.14
CARP	MICH	1984	11	1.03	25.70	8.49	1.97		5.86		50.3	1769	5.60	1.35
	MICH	1985	20	0.20	9.12	3.59	3.24		7.00		47.9	1602	5.51	1.45
	MICH	1986	24	0.51	10.50	4.26	1.56		3.08		52.3	2335	7.71	1.52
	MICH	1987	9	1.02	8.64	4.45	2.33		3.96		50.9	1983	5.69	1.48
	BBL	1999	11	0.71	3.40	1.81	1.31	1.33	1.71	1.68	57.3	2791	6.01	1.42
	LTM	1999	11	0.69	6.48	2.69	1.61	1.69	2.10	2.12	58.5	3044	11.39	1.46
	LTM	2001	11	0.06	3.84	1.63	0.83	0.87	1.20	2.64	54.6	2214	2.10	1.34
CHANNEL CATFISH	MICH	1987	8	3.45	12.41	6.36					50.6	1615	10.09	1.14
	BBL	1999	4	0.30	4.80	2.53					58.3	2488	11.05	1.22
	LTM	2001	2	3.00	3.83	3.41					50.6	2070	2.00	1.69
FLTH. CATFISH	MICH	1987	3	1.71	22.20	13.71					79.6	5953	3.61	1.12
FRESHWATER DRUM	MICH	1987	2	0.54	1.78	1.16					37.1	840	3.90	1.48
LARGEMOUTH BASS	MICH	1985	9	0.48	2.97	1.33					35.4	707	0.79	1.54
	MICH	1986	5	0.06	1.09	0.56					37.3	866	0.82	1.58

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg) Site-wide		Adjusted[1,2] PCB (mg/kg) ABSA-specific		Length	Weight	Lipid	Condition[5]
				Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	(cm)	(g)	%	10,000xg/cm[3]
SAUGATUCK														
LARGEMOUTH BASS	MICH	1987	10	0.52	2.02	1.10					35.2	806	0.89	1.77
NORTHERN PIKE	MICH	1987	10	0.36	3.36	1.33					60.2	1654	1.60	0.68
	BBL	1999	4	0.09	0.51	0.26					64.0	1788	0.90	0.68
RAINBOW TROUT	MICH	1987	10	0.24	0.73	0.44					59.9	2702	6.97	1.22
ROCK BASS	MICH	1987	10	0.17	0.52	0.37					18.1	154	0.53	2.60
SMALLMOUTH BASS	MICH	1985	1	1.71	1.71	1.71					29.5	280	0.90	1.09
	BBL	1999	11	0.16	0.65	0.32	0.22	0.22	0.30	0.30	38.9	1000	1.38	1.63
	LTM	1999	11	0.20	1.16	0.53	0.33	0.33	0.45	0.45	40.4	1144	1.89	1.48
	LTM	2001	11	0.26	1.18	0.54	0.45	0.45	0.61	0.61	33.1	606	1.62	1.46
WALLEYE	MICH	1987	10	0.33	1.48	0.58					44.6	1036	1.38	1.13
	BBL	1999	8	0.07	0.39	0.18					48.7	1428	0.95	1.10
WHITE SUCKER	MICH	1987	10	0.44	2.82	1.08					47.7	1364	3.15	1.23
YELLOW PERCH	MICH	1987	10	0.06	1.20	0.43					18.9	109	0.46	1.57
SAUGATUCK RIVER MOUTH														
CARP	MICH	1993	5	1.09	1.09	1.09					51.6	2282	4.75	1.62

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

Species	Source[3]	Year	N	Wet Weight PCB (mg/kg) Min	Max	Avg.	Adjusted[1,2] PCB (mg/kg) Site-wide Model I[4]	Site-wide Model II	ABSA-specific Model I	ABSA-specific Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm[3]
VARIOUS														
WALLEYE	MICH	1993	13	0.17	3.71	1.01					50.3	1299	1.14	0.96
MONARCH MILL POND														
CARP	LTM	2001	11	0.05	0.47	0.18					62.0	3428	2.16	1.41
FORMER BRYANT MILL POND														
BROWN TROUT	LTM	2000	1	0.05	0.05	0.05					22.0	98	0.80	0.92
CARP	MICH	1985	10	1.57	4.50	3.04	10.01		4.65		45.5	1334	0.60	1.40
	MICH	1986	21	0.81	27.37	3.97	5.78		2.68		46.2	1452	1.21	1.44
	MICH	1987	10	0.54	5.50	1.92	4.32		2.01		50.0	1847	0.83	1.43
	BBL	1993	11	1.52	8.79	3.42	4.56		2.12		50.5	1955	1.51	1.49
	LTM	2000	11	0.05	1.25	0.36	0.30		0.30		55.2	2580	2.12	1.51
	LTM	2001	11	0.13	3.66	0.72	0.44		0.44		53.4	2477	3.02	1.61

Note: See footnotes on page 17

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SUMMARY OF FILLET DATA

				Wet Weight PCB (mg/kg)			Adjusted[1,2] PCB (mg/kg)							
							Site-wide		ABSA-specific					
Species	Source[3]	Year	N	Min	Max	Avg.	Model I[4]	Model II	Model I	Model II	Length (cm)	Weight (g)	Lipid %	Condition[5] 10,000xg/cm^3

Notes:
1) Concentrations below detection were replaced with half the detection limits.
2) Adjusted PCB concentrations account for covariation between PCB, lipid and length so that carp are adjusted to geometric mean length (50.9 cm) and lipid (1.97%) and Smallmouth Bass are adjusted to geometric mean length (33.1 cm) and lipid (0.70%).
3) Data Sources include MICH (Michigan Department of Community Health), BBL (Blasland Bouck and Lee for Kalamazoo river Study Group), and LTM (MichiganDepartment of Environmental Quality long term monitoring program).
4) Model I adjustements are based on fish collected from 1983 through 2001. Model II adjustments exclude fish collected prior to 1990.
5) Condition index is 10,000 times mass in grams divided by length cubed.

Note: See footnotes on page 17

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

ABSA WHERE FILLET PCB CONCENTRATION WAS CORRELATED WITH
LIPID FRACTION AND OR FISH LENGTH AT THE 0.05 LEVEL OF SIGNIFICANCE

ABSA Name	Species	Lipid	Length
BATTLE CREEK	Carp	X	
	Smallmouth	X	X
MORROW POND	Carp	X	X
	Smallmouth	X	
DOWNSTREAM OF MORROW DAM	Carp	X	
	Smallmouth	X	
MOSEL AVENUE	Carp	X	
	Smallmouth	X	
PLAINWELL DAM	Carp	X	X
	Smallmouth	X	X
OTSEGO CITY DAM	Carp	X	X
	Smallmouth	X	
OTSEGO DAM	Carp	X	
	Smallmouth	X	
TROWBRIDGE DAM	Carp	X	
	Smallmouth	X	
LAKE ALLEGAN	Carp	X	X
	Smallmouth	X	
NEW RICHMOND	Carp	X	
	Smallmouth	X	
SAUGATUCK	Carp	X	X
	Smallmouth	X	X
FORMER BRYANT MILL POND	Carp	X	

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
BATTLE CREEK									
Carp									
intercept	Intercept	-2.88	0.24			-1.45	0.26		
Year	1991	1.44	0.35						
	1993	0.32	0.29			-1.12	0.31		
	1997	0.66	0.32			-0.78	0.34		
	1999	-0.40	0.41			-1.84	0.43		
	2000	0.10	0.48			-1.34	0.50		
	2001	1.82	0.41			0.38	0.43		
Lipid	Lipid	0.82	0.24			1.66	0.46		
Lipid*Year	Lipid*1991	0.84	0.51	2.71	0.022				
	Lipid*1993	-0.48	0.36			-1.32	0.54	2.93	0.021
	Lipid*1997	0.23	0.42			-0.61	0.59		
	Lipid*1999	-0.01	0.42			-0.85	0.58		
	Lipid*2000	0.20	0.44			-0.64	0.60		
	Lipid*2001	-0.88	0.36			-1.72	0.54		
Smallmouth Bass									
Intercept	Intercept					-213.88	58.85		
Year	1993					214.29	59.01		
	1997					203.23	59.10		
	1999					209.97	58.90		
	2000					210.50	58.88		
	2001					207.26	58.93		
Lipid	Lipid					7.78	1.57		
Length	Length					62.96	17.50		
Lipid*Year	Lipid*1993					-6.51	1.59	5.81	<0.001
	Lipid*1997					-7.58	1.58		
	Lipid*1999					-7.73	1.60		
	Lipid*2000					-7.78	1.58		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Parameter	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
BATTLE CREEK									
Smallmouth Bass									
Lipid*Year	Lipid*2001					-7.63	1.59	5.81	<0.001
Length*Year	Length*1983					-63.77	17.54	3.23	0.014
	Length*1997					-60.84	17.57		
	Length*1999					-62.85	17.52		
	Length*2001					-62.06	17.52		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Parameter	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
MORROW POND									
Carp									
intercept	Intercept	4.50	9.99			-1.29	5.26		
Year	1986	-24.09	15.57						
	1987	4.90	14.25						
	1993	-7.73	11.39						
	1997	-7.28	11.01			-1.50	6.69		
	1999	-13.99	10.39			-8.91	6.17		
	2001	2.76	10.89			9.27	6.28		
Lipid	Lipid	0.81	0.08	91.4	<0.001	0.91	0.12	43.3	<0.001
Length	Length	-1.04	2.58			0.18	1.27		
Length*Year	Length*1986	6.23	4.04	2.39	0.034				
	Length*1987	-1.38	3.66						
	Length*1983	1.69	2.90						
	Length*1997	1.52	2.82			0.33	1.64	4.58	0.006
	Length*1999	3.10	2.68			2.06	1.50		
	Length*2001	-1.05	2.80			-2.47	1.53		
Smallmouth Bass									
intercept	Intercept	0.43	0.29			-1.24	0.19		
Year	1987	-1.27	0.40						
	1993	-1.66	0.33						
	1997	-2.26	0.33			-0.59	0.29		
	1999	-2.11	0.30			-0.44	0.23		
	2001	-2.67	0.35			-1.01	0.32		
Lipid	Lipid	0.71	0.16	20.4	<0.001	0.71	0.18	15.9	<0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

			Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
DOWNSTREAM OF MORROW DAM										
Carp										
	Intercept	Intercept					0.81	0.26		
	Year	2000					-0.63	0.24		
	Lipid	Lipid					0.51	0.20	6.72	0.021
Smallmouth Bass										
	Intercept	Intercept					-0.19	0.15		
	Year	2000					-0.53	0.28		
	Lipid	Lipid					0.90	0.19	22.7	<0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Parameter	Model I Based on 1983 - 2001 Estimate	Model I Stderr	Model I F	Model I Significance	Model II Based on 1990 - 2001 Estimate	Model II Stderr	Model II F	Model II Significance
MOSEL AVENUE										
Carp										
	intercept	Intercept	0.54	0.14			0.69	0.16		
	Year	1985	0.94	0.17						
		1986	0.21	0.20						
		1993	0.00	0.27						
		1999	-1.02	0.53			-0.28	0.16		
		2000	0.21	0.30			-0.21	0.20		
	Lipid	Lipid	0.69	0.15			0.65	0.08	68.4	<0.001
	Lipid*Year	Lipid*1985	-0.36	0.17	3.15	0.013				
		Lipid*1986	-0.15	0.18						
		Lipid*1993	0.05	0.20						
		Lipid*1999	0.42	0.30						
		Lipid*2000	-0.17	0.19						
Smallmouth Bass										
	intercept	Intercept	1.47	0.38			-0.58	0.13		
	Year	1993	-2.04	0.37						
		1999	-1.80	0.38			0.24	0.17		
		2000	-1.80	0.40			0.25	0.17		
	Lipid	Lipid	0.70	0.15	20.7	<0.001	0.68	0.15	19.6	<0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
PLAINWELL DAM									
Carp									
intercept	Intercept	-7.46	2.19			-12.04	2.12		
Year	1985	0.49	0.20						
	1986	0.09	0.21						
	1987	-0.67	0.33						
	1993	-0.79	0.38						
	1997	-0.82	0.27			-0.31	0.15		
	1999	-0.48	0.41			-0.34	0.15		
	2001	-1.06	0.42			-0.33	0.16		
Lipid	Lipid	0.61	0.12			0.49	0.08	106.	<0.001
Length	Length	2.17	0.56			3.19	0.54	33.4	<0.001
Lipid*Year	Lipid*1985	-0.29	0.15	2.58	0.017				
	Lipid*1986	-0.29	0.17						
	Lipid*1987	0.22	0.25						
	Lipid*1993	0.10	0.26						
	Lipid*1997	-0.02	0.19						
	Lipid*1999	-0.18	0.20						
	Lipid*2001	0.11	0.23						
Smallmouth Bass									
Intercept	Intercept					0.40	4.53		
Year	1997					-38.06	16.15		
	1999					2.05	4.91		
	2001					-4.94	5.36		
Lipid	Lipid					0.63	0.16	27.1	<0.001
Length	Length					0.01	1.28		
Length*Year	Length*1997					10.41	4.47	2.97	0.041
	Length*1999					-0.76	1.39		
	Length*2001					1.19	1.54		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
PLAINWELL DAM									
Smallmouth Bass									

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

			Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
OTSEGO CITY DAM										
Carp										
	Intercept	Intercept					-7.33	3.90		
	Year	1999					-0.74	0.31		
		2001					-0.22	0.27		
	Lipid	Lipid					0.51	0.17	10.6	0.002
	Length	Length					1.98	0.97	4.99	0.034
Smallmouth Bass										
	Intercept	Intercept					-0.26	0.27		
	Year	1999					-0.44	0.35		
		2001					0.73	0.55		
	Lipid	Lipid					-0.13	0.42		
	Lipid*Year	Lipid*1999					-0.12	0.55	6.98	0.002
		Lipid*2001					1.67	0.57		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Parameter	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
OTSEGO DAM									
Carp									
Intercept	Intercept					0.06	0.18		
Year	1999					-0.29	0.22		
	2001					0.11	0.25		
Lipid	Lipid					1.04	0.14	51.5	<0.001
Smallmouth Bass									
Intercept	Intercept					0.49	0.13		
Year	1999					-1.05	0.38		
	2001					-1.13	0.22		
Lipid	Lipid					0.92	0.20		
Lipid*Year	Lipid*1999					-0.87	0.48	6.86	0.003
	Lipid*2001					-1.08	0.30		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
TROWBRIDGE DAM									
Carp									
Intercept	Intercept					1.25	0.19		
Year	1999					-0.61	0.23		
	2001					-0.40	0.28		
Lipid	Lipid					0.41	0.11	14.4	<0.001
Smallmouth Bass									
Intercept	Intercept					0.78	0.10		
Year	1999					-0.49	0.13		
	2001					-0.49	0.14		
Lipid	Lipid					0.79	0.12	42.8	<0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Parameter	Model I Based on 1983 - 2001 Estimate	Stderr	F	Significance	Model II Based on 1990 - 2001 Estimate	Stderr	F	Significance
LAKE ALLEGAN										
Carp										
	intercept	Intercept	-4.53	1.19			-4.11	2.47		
	Year	1986	0.16	0.17						
		1987	0.13	0.24						
		1990	0.05	0.28						
		1992	-0.59	0.29			-0.63	0.39		
		1993	-1.10	0.24			-1.13	0.36		
		1994	-0.41	0.25			-0.45	0.36		
		1997	-1.14	0.33			-1.16	0.45		
		1999	-1.48	0.21			-1.50	0.36		
		2000	-1.37	0.25			-1.39	0.37		
		2001	-1.42	0.29			-1.44	0.43		
	Lipid	Lipid	0.93	0.25			0.75	0.43		
	Length	Length	1.48	0.32			1.38	0.67		
	Lipid*Year	Lipid*1986	0.51	0.27	3.79	<0.001				
		Lipid*1987	0.24	0.59						
		Lipid*1990	-0.18	0.45						
		Lipid*1992	0.69	0.43			0.87	0.59	2.82	0.011
		Lipid*1993	0.22	0.38			0.39	0.54		
		Lipid*1994	0.48	0.57			0.66	0.73		
		Lipid*1997	-0.24	0.37			-0.06	0.53		
		Lipid*1999	-0.66	0.31			-0.48	0.48		
		Lipid*2000	1.12	0.45			1.30	0.60		
		Lipid*2001	-0.17	0.41			0.01	0.57		
Smallmouth Bass										
	intercept	Intercept	0.62	0.39			0.37	0.33		
	Year	1987	0.41	0.41						
		1993	-0.25	0.50						

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Parameter	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
LAKE ALLEGAN									
Smallmouth Bass									
Year	1997	-1.25	0.46			-1.00	0.42		
	1999	-1.25	0.40			-1.00	0.35		
	2000	-1.05	0.47			-0.80	0.43		
	2001	-0.80	0.43			-0.56	0.39		
Lipid	Lipid	-0.14	0.34			0.75	0.31		
Lipid*Year	Lipid*1987	1.06	0.48	3.49	0.004				
	Lipid*1993	0.89	0.45						
	Lipid*1997	0.47	0.41			-0.41	0.40	3.63	0.010
	Lipid*1999	0.24	0.37			-0.65	0.35		
	Lipid*2000	1.09	0.43			0.20	0.42		
	Lipid*2001	1.19	0.41			0.30	0.39		

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
NEW RICHMOND									
Carp									
Intercept	Intercept					2.09	0.65		
Year	1997					-2.29	0.79		
	1999					-2.29	0.71		
	2001					-2.14	0.72		
Lipid	Lipid					-0.37	0.33		
Lipid*Year	Lipid*1997					1.19	0.42	3.31	0.027
	Lipid*1999					1.04	0.38		
	Lipid*2001					1.21	0.47		
Smallmouth Bass									
Intercept	Intercept					-0.64	0.22		
Year	1997					0.58	0.33		
	1999					0.11	0.27		
	2001					0.24	0.32		
Lipid	Lipid					0.45	0.22	3.99	0.051

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

		Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
	Parameter	Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
SAUGATUCK									
Carp									
intercept	Intercept	-0.68	6.27			-1.25	6.79		
Year	1985	-36.57	13.66						
	1986	2.79	7.42						
	1987	4.53	11.03						
	1999	-0.08	8.54						
	2001	-35.63	11.91			-33.38	12.83		
Lipid	Lipid	1.31	0.24			0.27	0.17	5.13	0.030
Length	Length	0.09	1.63			0.34	1.70		
Lipid*Year	Lipid*1985	-0.68	0.33	2.60	0.030				
	Lipid*1986	-0.47	0.30						
	Lipid*1987	-0.64	0.36						
	Lipid*1999	-1.00	0.29						
	Lipid*2001	-1.15	0.36						
Length*Year	Length*1985	9.56	3.57	4.21	0.001				
	Length*1986	-0.70	1.94						
	Length*1987	-0.99	2.86						
	Length*1999	0.10	2.19						
	Length*2001	9.00	3.03			8.33	3.20	6.78	0.014
Smallmouth Bass									
Intercept	Intercept					-5.97	1.27		
Year	2001					0.54	0.15		
Lipid	Lipid					0.22	0.16	4.76	0.037
Length	Length					1.34	0.35	13.1	0.001

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

REGRESSION COEFFICIENT ESTIMATES FOR LIPID AND LENGTH EFFECTS

	Parameter	Model I Based on 1983 - 2001				Model II Based on 1990 - 2001			
		Estimate	Stderr	F	Significance	Estimate	Stderr	F	Significance
FORMER BRYANT MILL POND									
Carp									
intercept	Intercept	1.66	0.22			0.66	0.28		
Year	1986	-0.67	0.26						
	1987	-0.90	0.29						
	1993	-0.97	0.31						
	2000	-4.02	0.33			-3.09	0.37		
	2001	-3.51	0.35			-2.60	0.39		
Lipid	Lipid	1.07	0.15	52.3	<0.001	1.17	0.31	14.2	<0.001

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA[2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
BATTLE CREEK													
CARP	1983-2001	ABSA-specific	-1.8	-9.3	6.3	0.747	1.45	-1.00	2.39	0.822	0.82	0.62	1.30
	1983-2001	Site-wide	-1.3	-10.4	10.0	0.699	0.21	-1.00	2.24	0.978	0.83	0.65	1.48
	1990-2001	ABSA-specific	2.7	-13.7	38.1	0.291	1.78	-0.26	3.47	0.210	0.85	0.59	1.34
	1990-2001	Site-wide	3.9	-16.7	75.6	0.192	1.26	-0.22	3.18	0.186	0.85	0.62	1.40
SMALLMOUTH BASS	1990-2001	ABSA-specific	9.4	3.0	18.7	0.002	-0.35	-0.81	0.54	0.312	0.31	0.19	0.37
	1990-2001	Site-wide	10.4	4.2	18.9	<0.001	-0.31	-0.61	0.58	0.448	0.31	0.19	0.36
MORROW POND													
CARP	1983-2001	ABSA-specific	10.0	4.8	19.0	<0.001	0.49	-0.22	0.65	0.148	0.60	0.44	0.99
	1983-2001	Site-wide	10.1	5.9	16.3	<0.001	0.50	-0.11	0.64	0.122	0.58	0.44	0.80
	1990-2001	ABSA-specific	10.3	2.7	20.2	0.004	-0.31	-0.58	1.34	0.904	0.46	0.34	0.53
	1990-2001	Site-wide	9.6	0.2	26.9	0.02	0.52	-0.19	2.35	0.104	0.50	0.38	0.58
SMALLMOUTH BASS	1983-2001	ABSA-specific	16.3	9.5	24.6	<0.001	0.51	-0.24	0.74	0.256	0.58	0.49	0.67
	1983-2001	Site-wide	16.3	9.7	24.0	<0.001	0.51	-0.24	0.75	0.256	0.58	0.49	0.67
	1990-2001	ABSA-specific	11.2	4.8	19.6	0.001	-0.29	-0.50	0.81	0.568	0.60	0.48	0.70
	1990-2001	Site-wide	11.2	5.0	18.2	0.001	-0.29	-0.53	0.80	0.556	0.60	0.48	0.70
DOWNSTREAM OF MORROW DAM													
CARP	1990-2001	ABSA-specific	7.9	2.3	15.1	<0.001	0.20	0.14	0.20	0.000	0.41	0.24	0.46
	1990-2001	Site-wide	7.9	2.6	13.9	<0.001	0.01	0.01	0.01	0.000	0.41	0.24	0.46
SMALLMOUTH BASS	1990-2001	ABSA-specific	7.5	1.0	13.6	0.015	0.21	-0.16	0.49	0.102	0.46	0.28	0.55
	1990-2001	Site-wide	7.5	1.0	13.5	0.015	0.01	0.01	0.01	0.000	0.46	0.28	0.55

Note: See footnotes on page 4

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA[2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
MOSEL AVENUE													
CARP	1983-2001	ABSA-specific	3.4	1.0	5.0	0.009	-0.70	-1.00	3.21	0.334	0.41	0.32	0.53
	1983-2001	Site-wide	4.2	0.6	6.3	0.016	-0.55	-1.00	2.83	0.356	0.45	0.36	0.63
	1990-2001	ABSA-specific	3.9	0.3	9.0	0.02	1.21	-1.00	2.37	0.576	0.33	0.19	0.41
	1990-2001	Site-wide	3.9	0.3	7.8	0.02	1.21	-1.00	2.37	0.620	0.33	0.19	0.41
SMALLMOUTH BASS	1983-2001	ABSA-specific	9.8	3.2	17.3	<0.001	0.83	0.56	2.05	0.000	0.50	0.38	0.63
	1983-2001	Site-wide	9.8	3.0	20.3	0.002	0.83	0.44	2.21	0.048	0.50	0.38	0.70
	1990-2001	ABSA-specific	-3.6	-8.3	0.0	0.976	-1.00	-1.00	1.23	0.974	0.36	0.24	0.45
	1990-2001	Site-wide	-3.5	-8.6	0.0	0.976	-1.00	-1.00	1.35	0.982	0.36	0.24	0.45
PLAINWELL DAM													
CARP	1983-2001	ABSA-specific	5.4	1.9	9.3	0.003	1.22	-0.60	3.22	0.244	0.46	0.33	0.55
	1983-2001	Site-wide	5.8	1.9	8.2	0.003	1.12	-0.52	2.94	0.344	0.48	0.37	0.60
	1990-2001	ABSA-specific	4.7	-0.1	9.1	0.026	1.03	-0.93	4.09	0.212	0.33	0.27	0.36
	1990-2001	Site-wide	4.6	-0.1	8.4	0.026	-0.02	-0.93	3.90	0.632	0.33	0.27	0.36
SMALLMOUTH BASS	1990-2001	ABSA-specific	8.5	0.8	17.4	0.018	0.59	-0.29	2.23	0.100	0.63	0.36	1.00
	1990-2001	Site-wide	8.5	0.8	16.7	0.019	0.59	-0.30	2.31	0.102	0.63	0.36	1.01
OTSEGO CITY DAM													
CARP	1990-2001	ABSA-specific	5.4	-1.2	14.7	0.055	0.88	0.05	3.55	0.048	0.63	0.45	0.72
	1990-2001	Site-wide	5.4	-1.2	14.7	0.055	0.88	-0.01	3.49	0.054	0.63	0.45	0.72
SMALLMOUTH BASS	1990-2001	ABSA-specific	1.8	-6.5	14.6	0.402	2.62	0.20	4.16	0.026	0.78	0.59	0.89
	1990-2001	Site-wide	1.5	-6.7	13.8	0.431	3.16	0.01	4.08	0.032	0.78	0.59	0.89

Note: See footnotes on page 4

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA [2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
OTSEGO DAM													
CARP	1990-2001	ABSA-specific	0.0	-7.9	8.2	0.47	0.20	0.20	5.22	0.000	0.51	0.29	0.64
	1990-2001	Site-wide	0.0	-8.8	7.8	0.47	0.06	0.02	5.12	0.002	0.51	0.29	0.64
SMALLMOUTH BASS	1990-2001	ABSA-specific	7.3	3.2	13.3	<0.001	0.65	-0.62	1.32	0.294	0.34	0.24	0.39
	1990-2001	Site-wide	10.3	6.2	15.7	<0.001	0.46	-0.41	0.72	0.394	0.34	0.24	0.41
TROWBRIDGE DAM													
CARP	1990-2001	ABSA-specific	7.5	1.8	14.2	0.01	0.67	-0.48	1.96	0.136	0.61	0.44	0.72
	1990-2001	Site-wide	7.5	1.8	14.3	0.01	0.67	-0.48	1.96	0.140	0.61	0.43	0.72
SMALLMOUTH BASS	1990-2001	ABSA-specific	7.3	4.2	11.0	<0.001	0.67	-0.54	1.06	0.238	0.32	0.24	0.37
	1990-2001	Site-wide	7.3	4.2	10.8	<0.001	0.67	-0.54	1.06	0.262	0.32	0.24	0.37
LAKE ALLEGAN													
CARP	1983-2001	ABSA-specific	8.6	7.3	10.0	<0.001	-0.10	-0.27	0.39	0.554	0.58	0.48	0.66
	1983-2001	Site-wide	9.8	7.5	13.5	<0.001	-0.10	-0.23	0.37	0.708	0.66	0.55	0.83
	1990-2001	ABSA-specific	14.1	7.4	24.3	0.001	0.41	-0.08	0.63	0.054	0.65	0.50	0.76
	1990-2001	Site-wide	16.7	6.5	31.6	<0.001	0.35	-0.16	0.61	0.198	0.77	0.58	1.02
SMALLMOUTH BASS	1983-2001	ABSA-specific	15.4	11.3	21.2	<0.001	0.35	-0.25	0.67	0.358	0.42	0.33	0.61
	1983-2001	Site-wide	15.4	11.1	21.2	<0.001	0.35	-0.25	0.67	0.374	0.41	0.33	0.59
	1990-2001	ABSA-specific	10.7	-0.5	25.1	0.031	0.49	0.24	2.52	0.014	0.43	0.33	0.64
	1990-2001	Site-wide	10.7	-0.5	25.2	0.031	0.48	0.21	2.36	0.022	0.43	0.33	0.63

Note: See footnotes on page 4

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

MIXED ORDER MODEL PARAMETER ESTIMATES FOR SMALLMOUTH BASS AND CARP FILLETS

	DATA SUBSET	ADJUSTMENT[3]	Average Percent Reduction Per Year				THETA[1]				SIGMA [2]		
			Reduction	LCL 95	UCL 95	PROB[4]	THETA	LCL 95	UCL 95	PROB[5]	Sigma	LCL 95	UCL 95
NEW RICHMOND													
CARP	1990-2001	ABSA-specific	10.5	0.7	25.4	0.021	0.48	-0.12	1.97	0.074	0.72	0.56	0.84
	1990-2001	Site-wide	21.6	7.1	55.8	0.001	0.24	0.12	0.52	0.026	0.76	0.58	0.90
SMALLMOUTH BASS	1990-2001	ABSA-specific	-1.7	-6.3	3.2	0.744	-1.00	-1.00	1.43	0.624	0.71	0.43	0.93
	1990-2001	Site-wide	-1.6	-6.3	3.2	0.744	-1.00	-1.00	1.71	0.376	0.71	0.43	0.93
SAUGATUCK													
CARP	1983-2001	ABSA-specific	7.5	4.0	10.1	<0.001	0.72	-0.37	1.45	0.440	0.62	0.47	0.76
	1983-2001	Site-wide	4.5	0.7	8.0	0.013	-0.54	-1.00	3.85	0.790	0.63	0.47	0.79
	1990-2001	ABSA-specific	-11.4	-82.7	23.0	0.715	0.01	0.01	0.01	0.000	0.66	0.42	0.74
	1990-2001	Site-wide	30.0	-26.4	73.1	0.154	0.01	0.01	0.01	0.000	0.66	0.42	0.74
SMALLMOUTH BASS	1990-2001	ABSA-specific	-29.1	-49.9	-14.0	1	0.01	0.01	0.01	0.000	0.36	0.24	0.40
	1990-2001	Site-wide	-29.2	-48.6	-14.6	1	0.01	0.01	0.01	0.000	0.36	0.24	0.40
FORMER BRYANT MILL POND													
CARP	1983-2001	ABSA-specific	6.7	1.6	10.3	0.01	0.99	0.59	3.29	0.000	0.50	0.37	0.60
	1983-2001	Site-wide	4.7	0.9	8.0	0.01	0.99	0.59	3.33	0.000	0.50	0.37	0.60

Notes:
1) Exponent in the MO differential equation $dC/dt = kC^{(1-\theta)}$
2) Estimated variance of log-normal error distribution.
3) Site-wide adjustment indicates that concentrations were adjusted to site-wide average length and lipid content, and ABSA-specific adjustment indicates that concentrations were adjusted to within ABSA average length and lipid content.
4) One sided test of the null hypothes of no reduction in adjusted concentration over the period of time monitored.
5) One tailed test of the null hypothesis that the decay rate is exponential.

Note: See footnotes on page 4

TABLE 5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB CONCENTRATION HALF TIME (YEARS) IN SMALLMOUTH BASS AND CARP FILLETS

Species	PCB Half Time (1983-2001)			PCB Half Time (1990-2001)		
	Half Time	LCL 95	UCL 95	Half Time	LCL 95	UCL 95
BATTLE CREEK						
CARP	Not Decreasing	28	Not Decreasing	415	9	Not Decreasing
Smallmouth Bass	11	7	24	10	6	23
MORROW POND						
CARP	6	5	8	14	6	Not Decreasing
Smallmouth Bass	6	5	10	8	5	51
DOWNSTREAM OF MORROW DAM						
CARP	6	4	23	6	4	23
Smallmouth Bass	12	5	Not Decreasing	12	5	Not Decreasing
MOSEL AVENUE						
CARP	23	11	Not Decreasing	12	6	68
Smallmouth Bass	Not Decreasing	52	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
PLAINWELL DAM						
CARP	13	9	25	23	9	Not Decreasing
Smallmouth Bass	7	4	32	7	4	29
OTSEGO CITY DAM						
CARP	16	6	Not Decreasing	16	6	Not Decreasing
Smallmouth Bass	8	3	Not Decreasing	8	3	Not Decreasing
OTSEGO DAM						
CARP	Not Decreasing	13	Not Decreasing	Not Decreasing	13	Not Decreasing
Smallmouth Bass	11	6	36	11	6	36

TABLE 5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB CONCENTRATION HALF TIME (YEARS) IN SMALLMOUTH BASS AND CARP FILLETS

Species	PCB Half Time (1983-2001)			PCB Half Time (1990-2001)		
	Half Time	LCL 95	UCL 95	Half Time	LCL 95	UCL 95
TROWBRIDGE DAM						
CARP	10	5	Not Decreasing	10	5	Not Decreasing
Smallmouth Bass	10	6	20	10	6	20
CITY OF ALLEGAN DAM						
CARP	Not Decreasing	21	Not Decreasing	Not Decreasing	21	Not Decreasing
Smallmouth Bass	4	2	12	4	2	12
LAKE ALLEGAN						
CARP	7	6	8	9	5	49
Smallmouth Bass	6	5	7	4	3	9
DOWNSTREAM OF ALLEGAN DAM						
CARP	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
Smallmouth Bass	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
NEW RICHMOND						
CARP	17	5	Not Decreasing	17	5	Not Decreasing
Smallmouth Bass	Not Decreasing	11	Not Decreasing	Not Decreasing	11	Not Decreasing
SAUGATUCK						
CARP	11	8	18	Not Decreasing	2	Not Decreasing
Smallmouth Bass	Not Decreasing	18	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
SAUGATUCK RIVER MOUTH						
CARP	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing	Not Decreasing
MONARCH MILL POND						
CARP	6	5	9	6	5	9

TABLE 5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB CONCENTRATION HALF TIME (YEARS) IN SMALLMOUTH BASS AND CARP FILLETS

	PCB Half Time (1983-2001)			PCB Half Time (1990-2001)		
Species	Half Time	LCL 95	UCL 95	Half Time	LCL 95	UCL 95
FORMER BRYANT MILL POND						
CARP	3	3	4	2	1	3

Figures

FIGURE 1.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SITE MAP

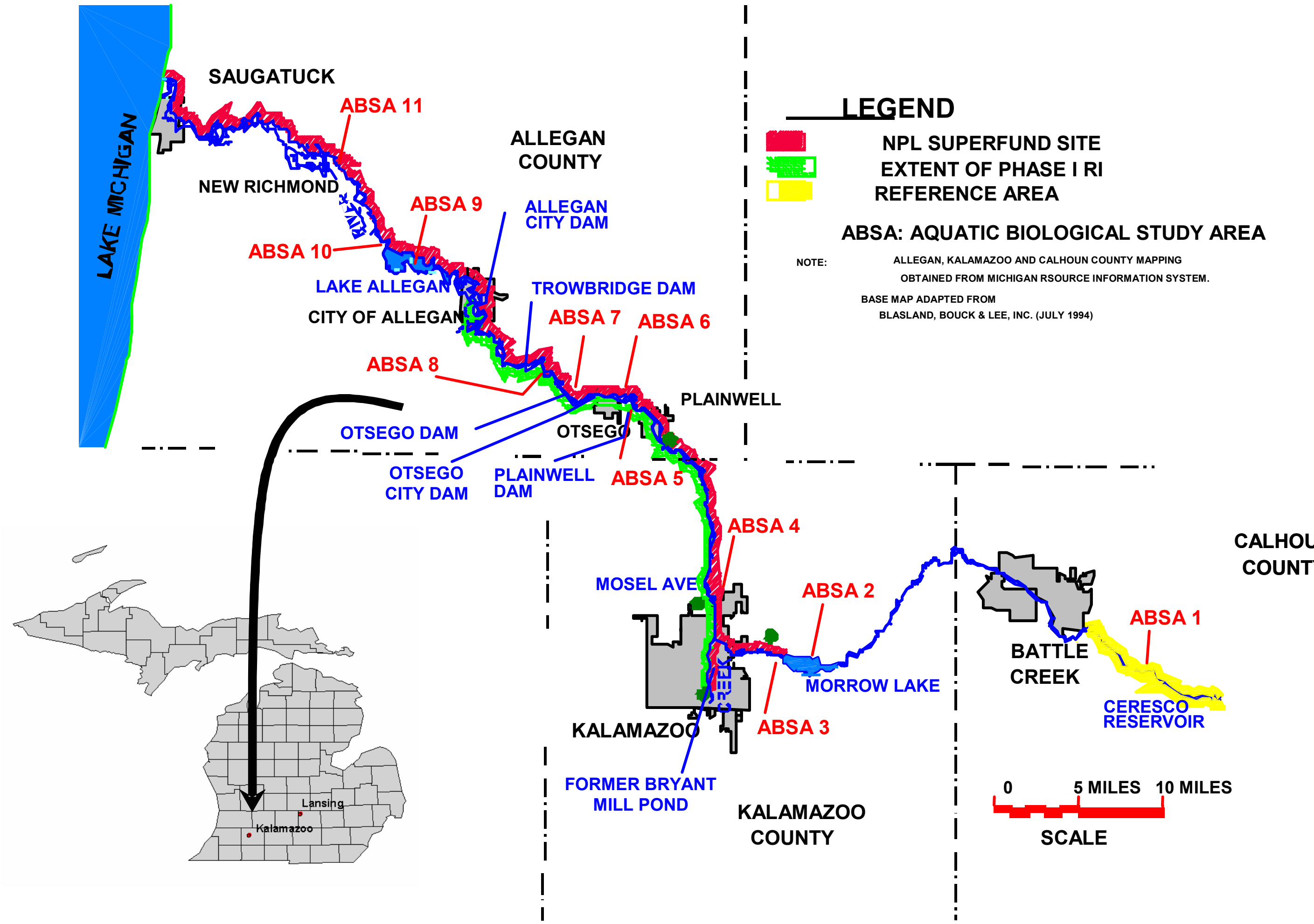


FIGURE 2.

ALLIED PAER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN WET- WEIGHT PCB CONCENTRATION
IN COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

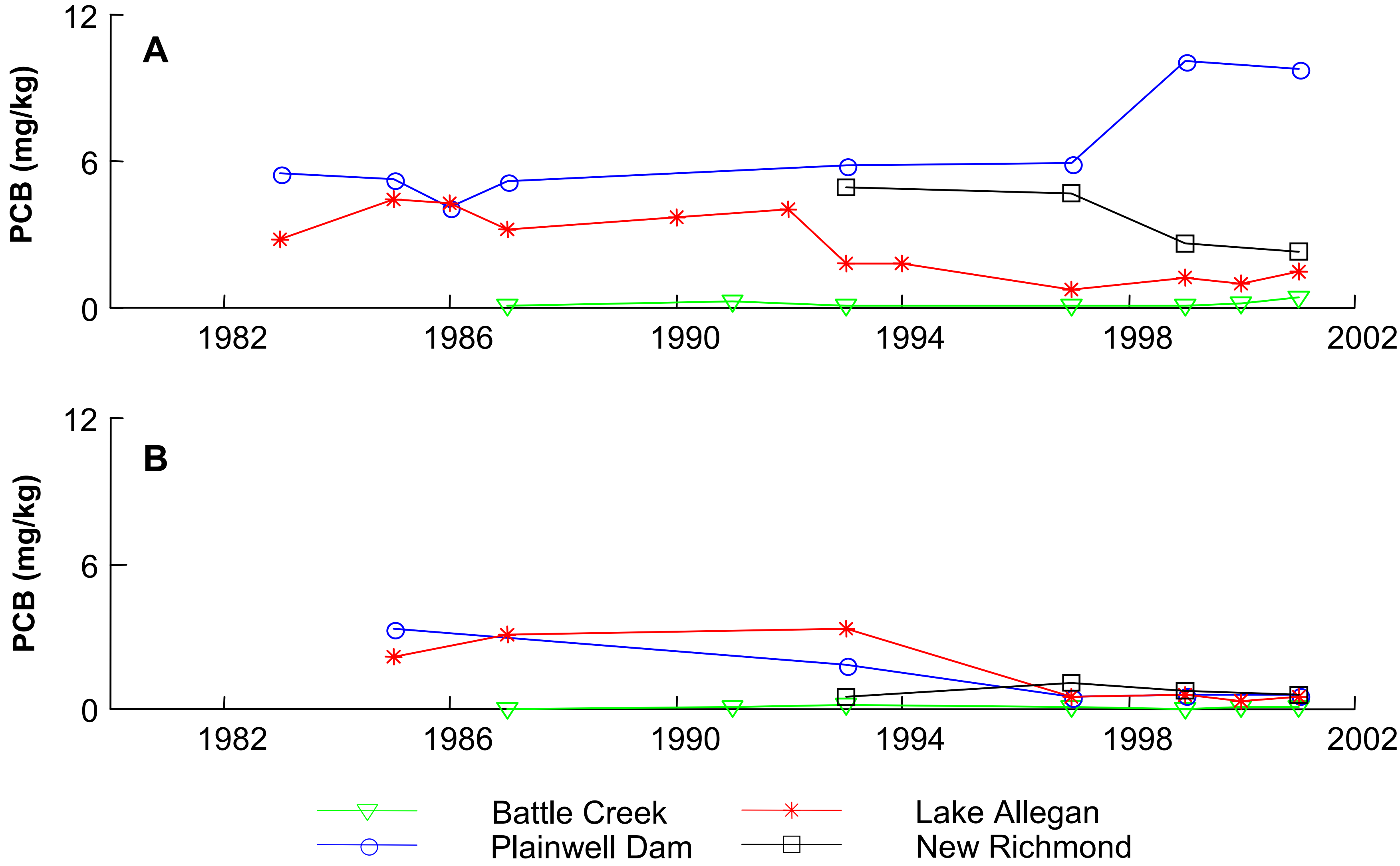


FIGURE 3.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN LIPID CONTENT
IN COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

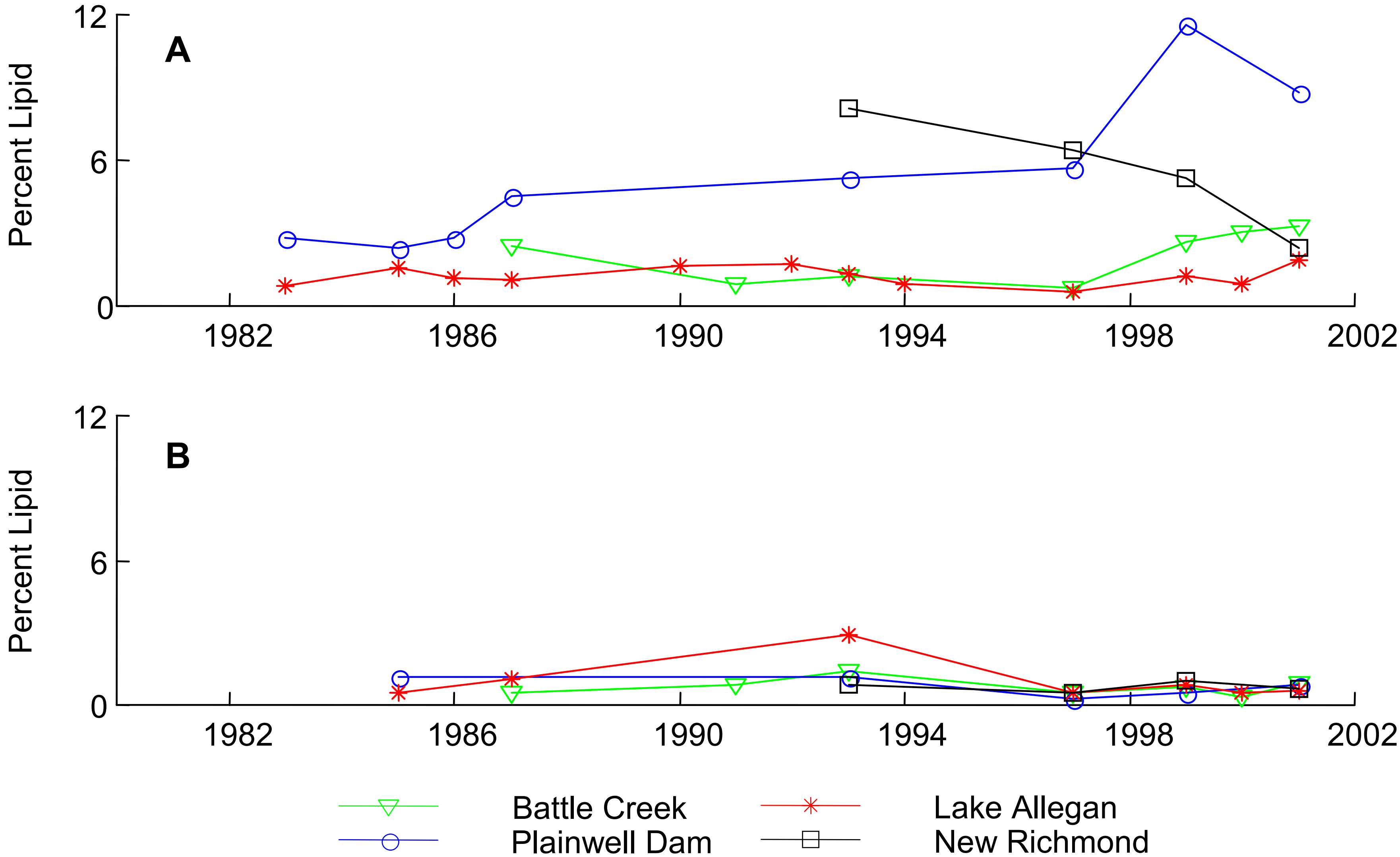


FIGURE 4.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN LENGTH
OF COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

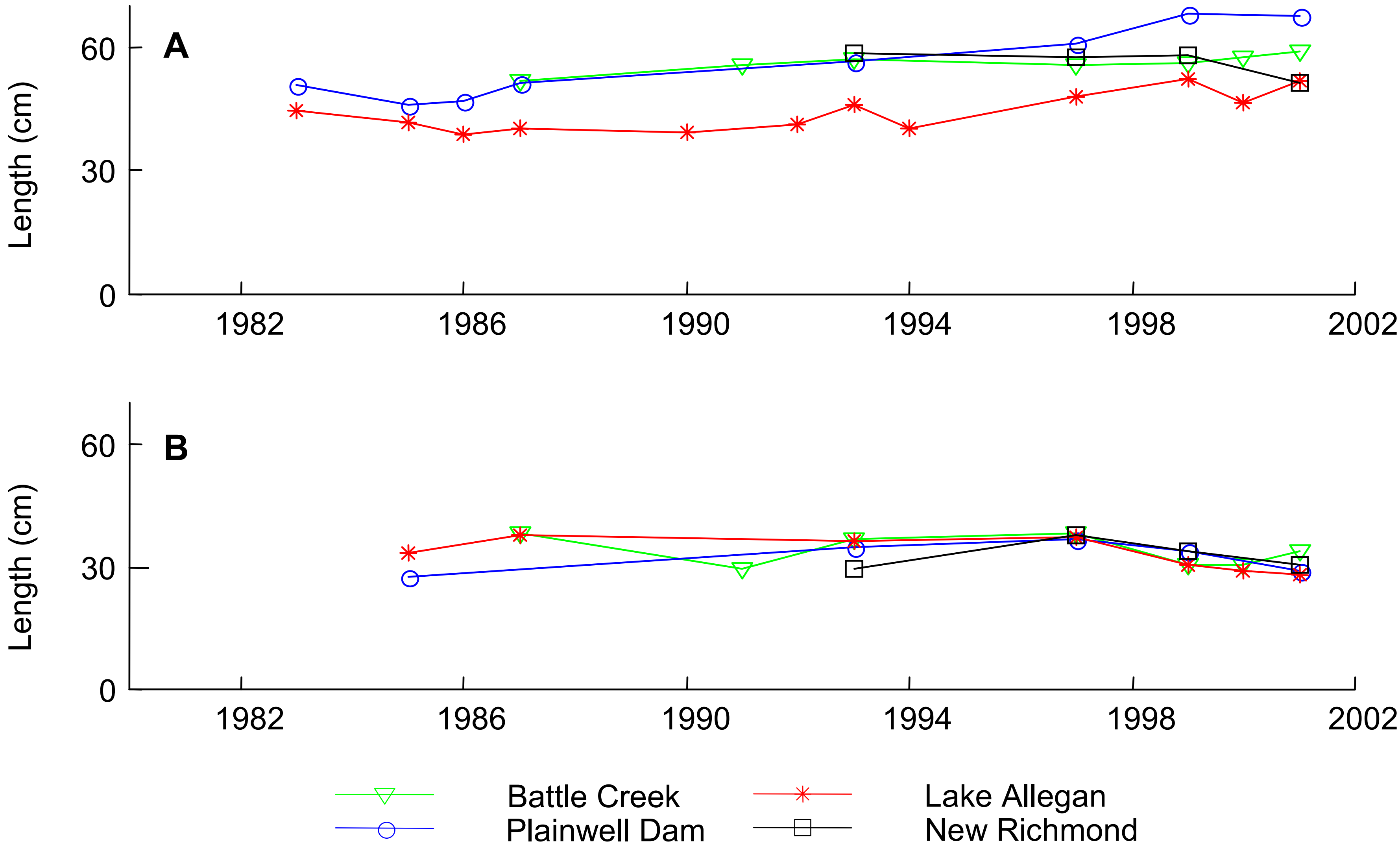


FIGURE 5.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN WEIGHT
OF COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

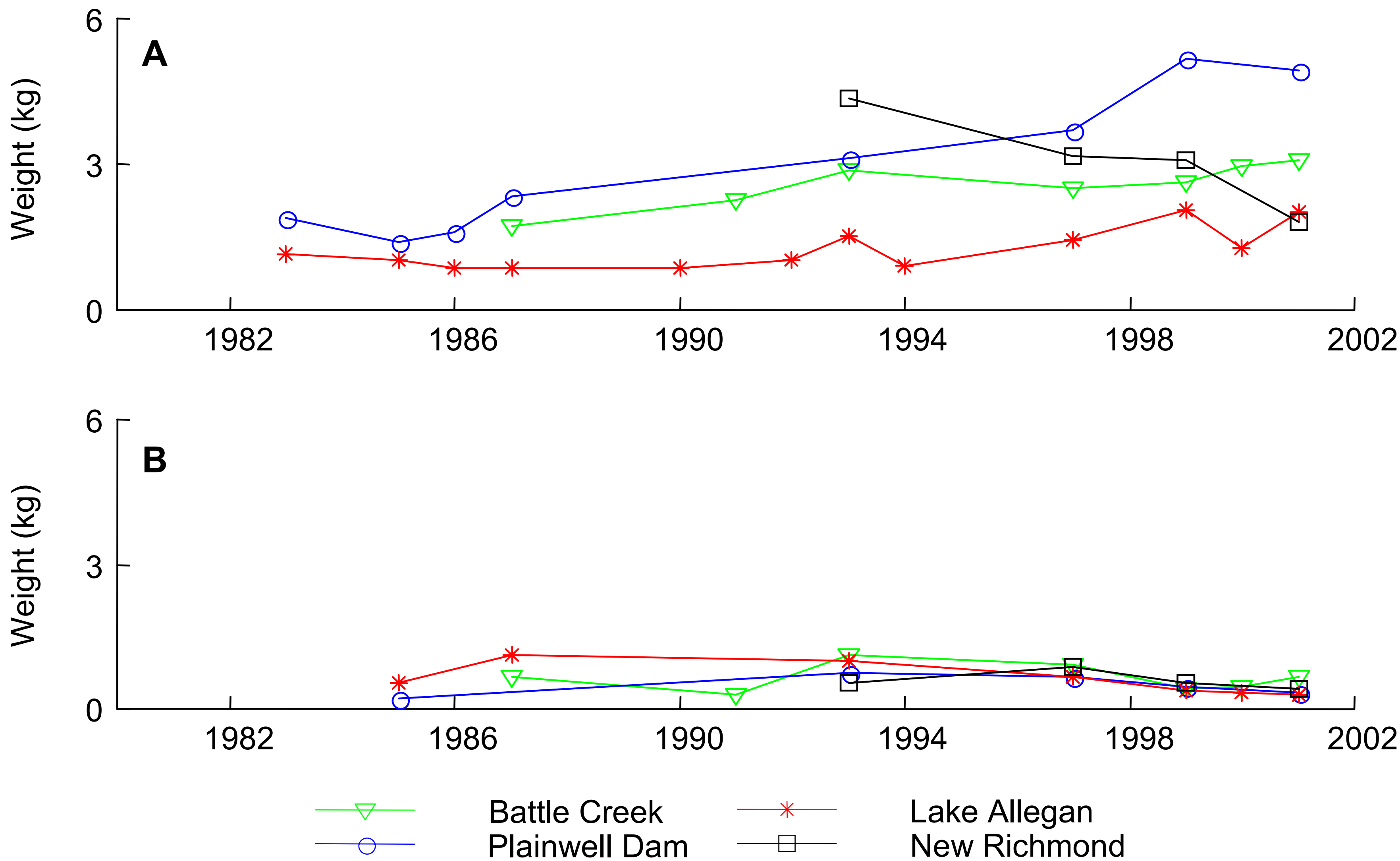


FIGURE 6.

ALLIED PAPER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN BODY CONDITION
OF COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

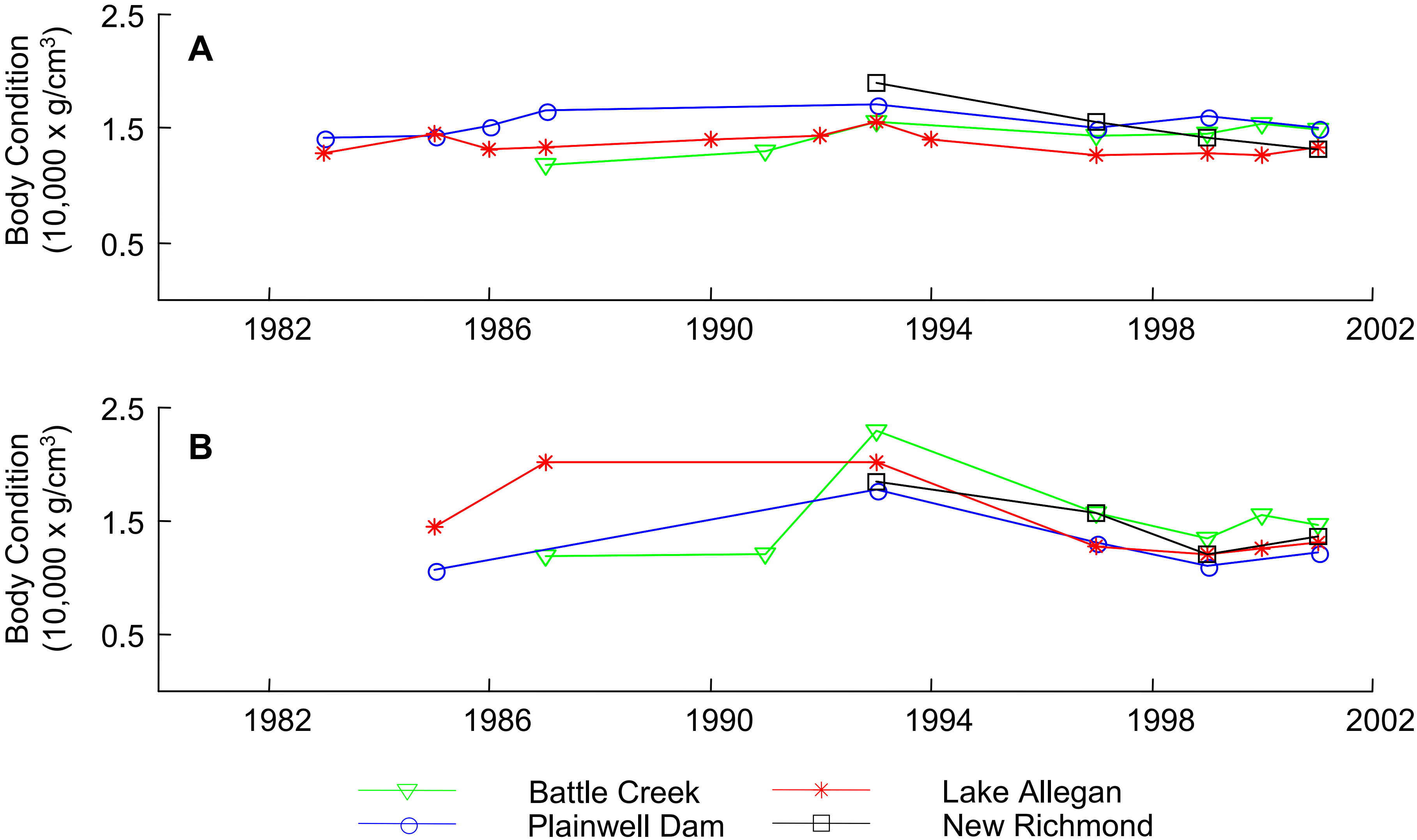


FIGURE 7.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN AVERAGE LENGTH, LIPID AND WET-WEIGHT PCB
IN CARP FILLETS AT LAKE ALLEGAN

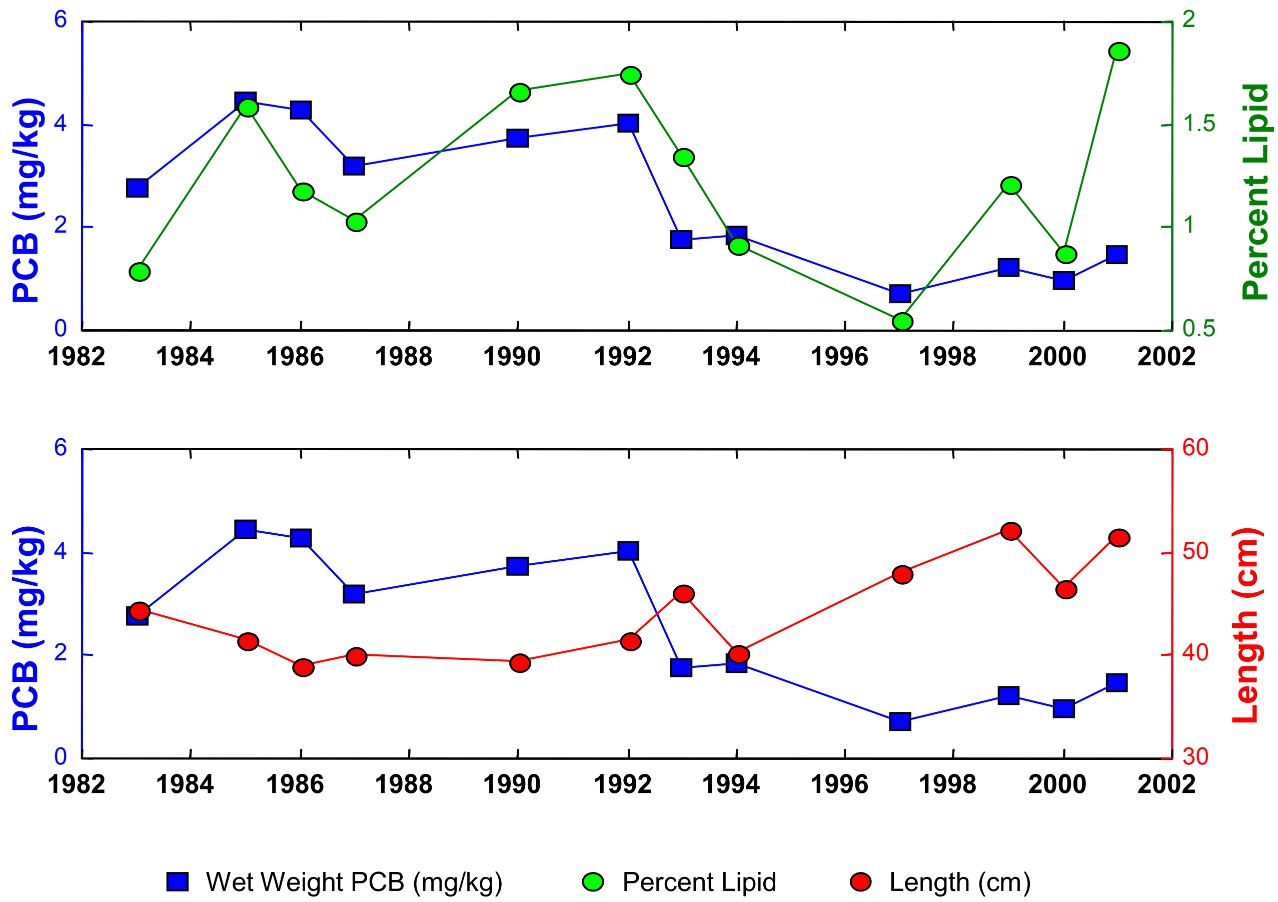


FIGURE 8.

ALLIED PAER, INC./ PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

SPATIAL AND TEMPORAL TRENDS IN ADJUSTED PCB CONCENTRATION
IN COMMON CARP (PANEL A) AND SMALLMOUTH BASS (PANEL B) FILLETS

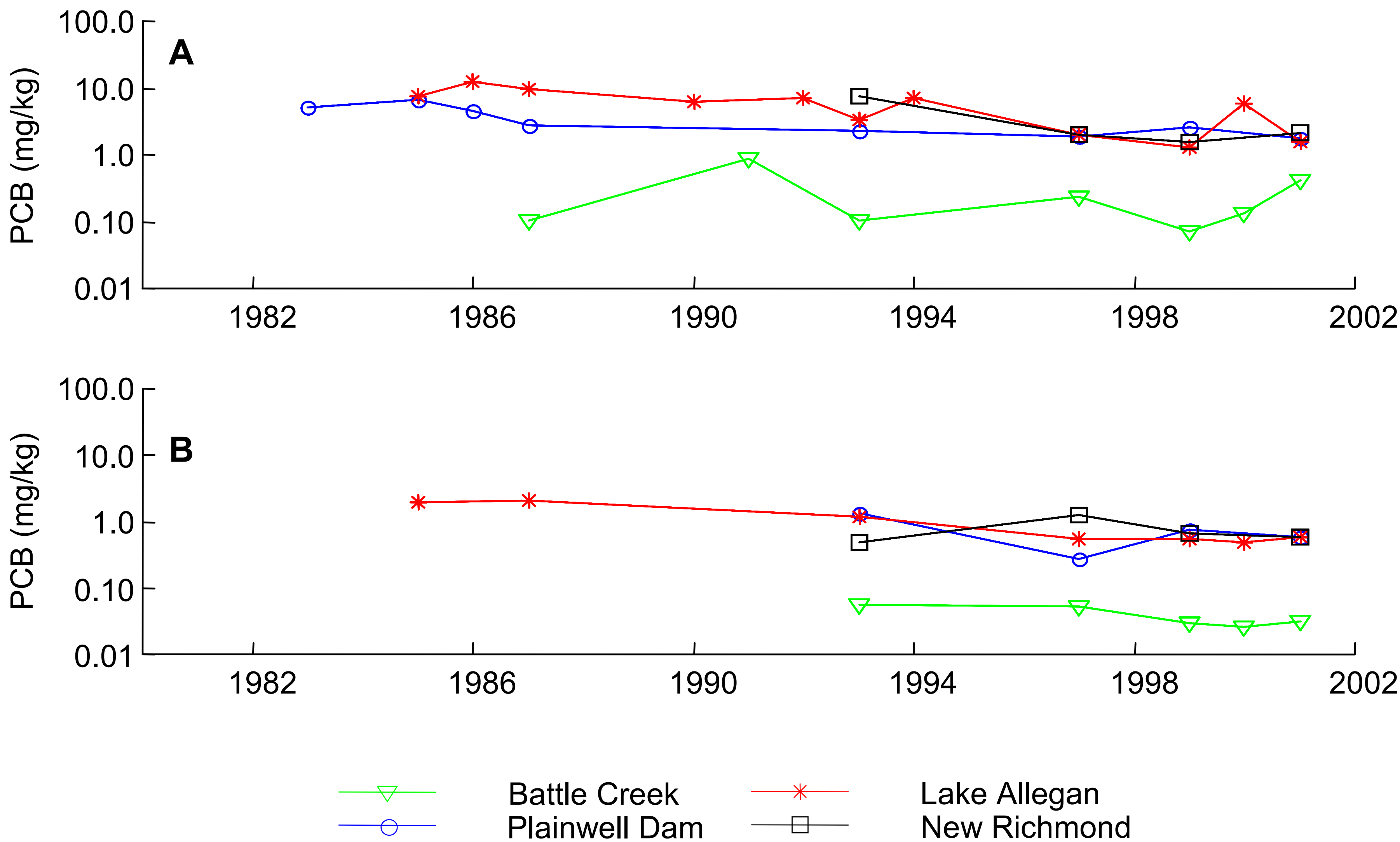


FIGURE 9.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED (SITE-WIDE) PCB CONCENTRATION
IN COMMON CARP AND SMALLMOUTH BASS FILLETS IN 2001
INDEX TO EXPOSURE THAT FISH RECEIVE

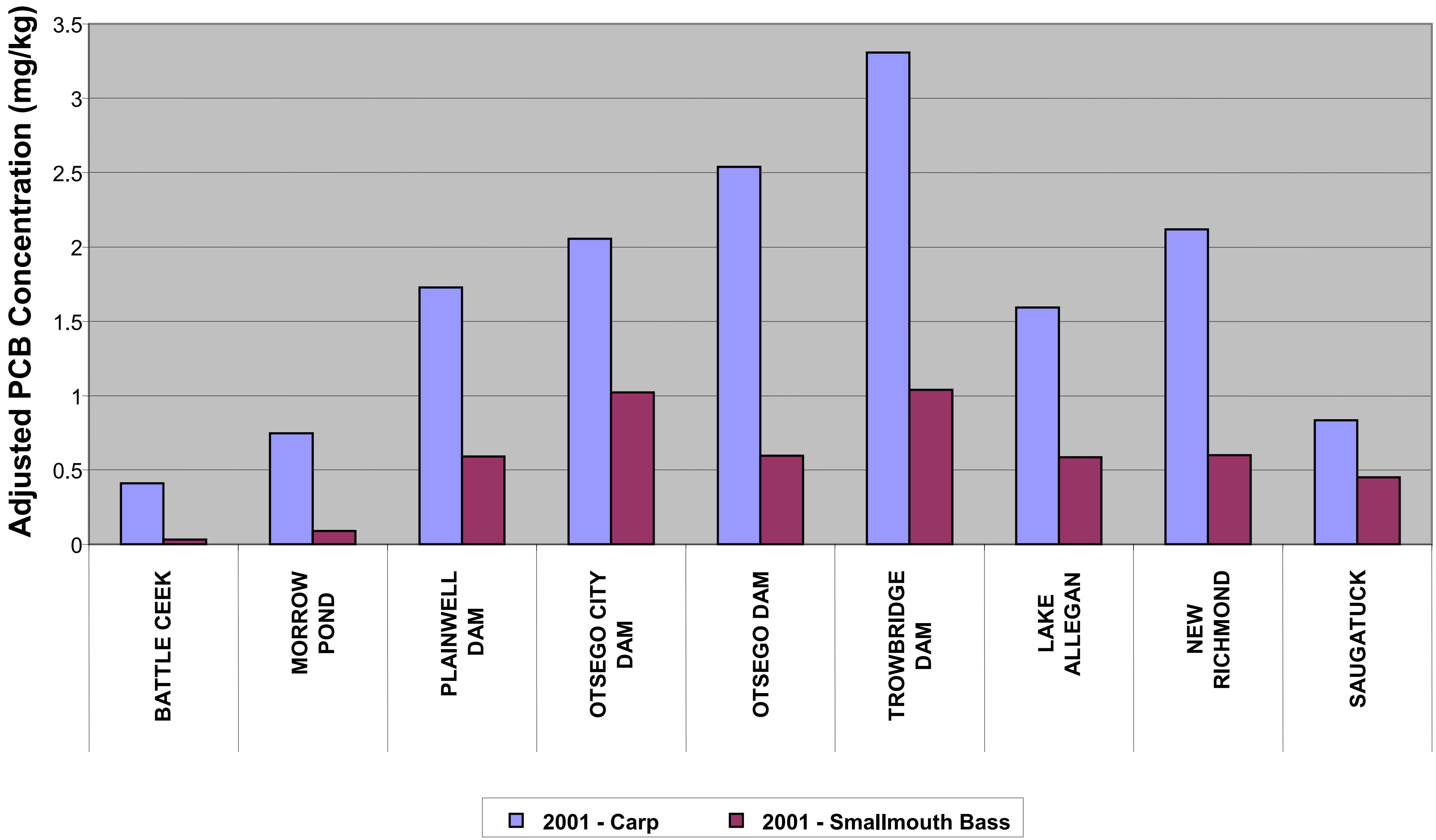


FIGURE 10.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED (ABSA-SPECIFIC) PCB CONCENTRATION
IN COMMON CARP AND SMALLMOUTH BASS FILLETS IN 2001
EXPECTED CHRONIC EXPOSURE FOR FISH CONSUMERS

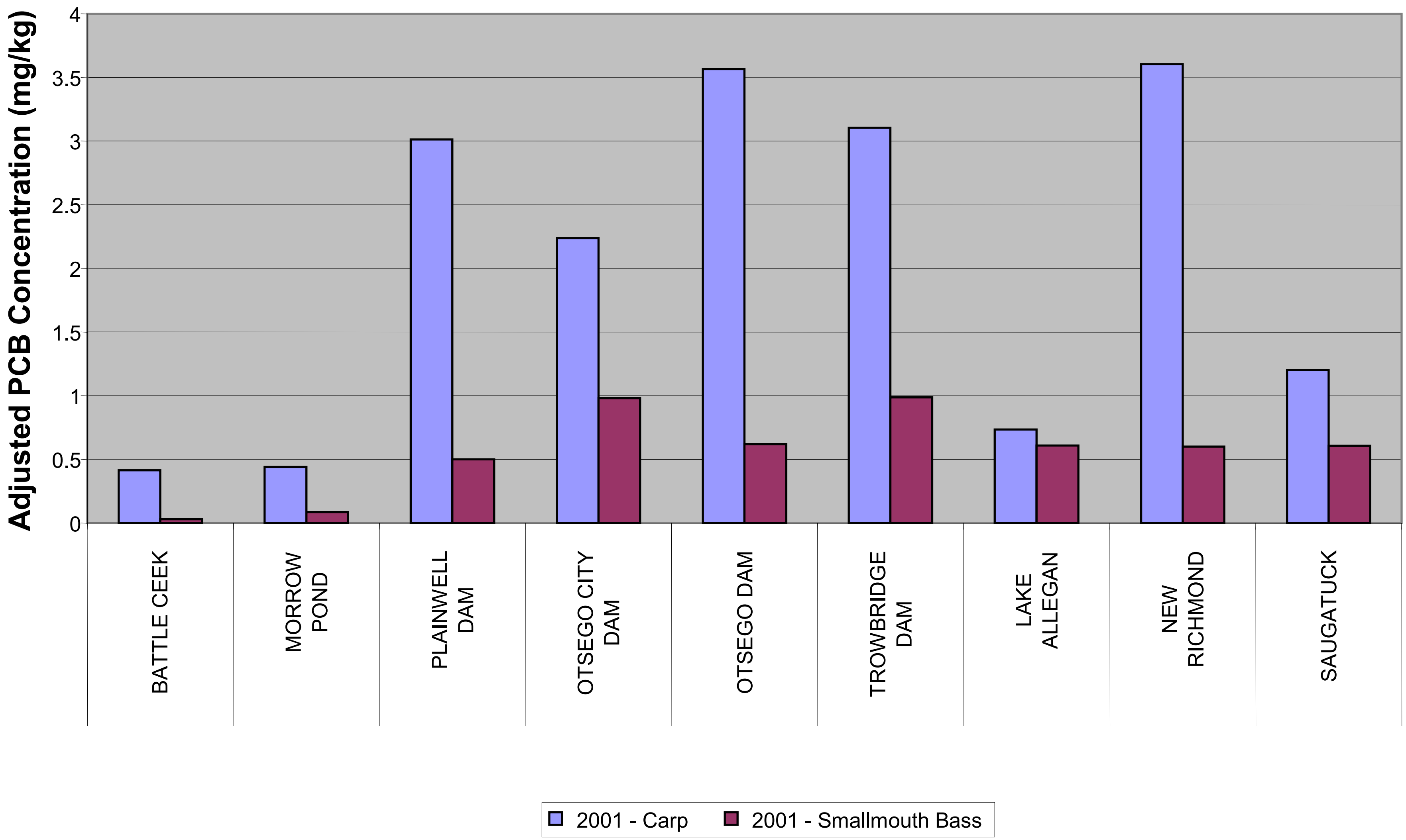


FIGURE 11.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT BATTLE CREEK FOR 1986-2001(PANELS A AND B) AND 1990-2001 (PANELS C AND D).

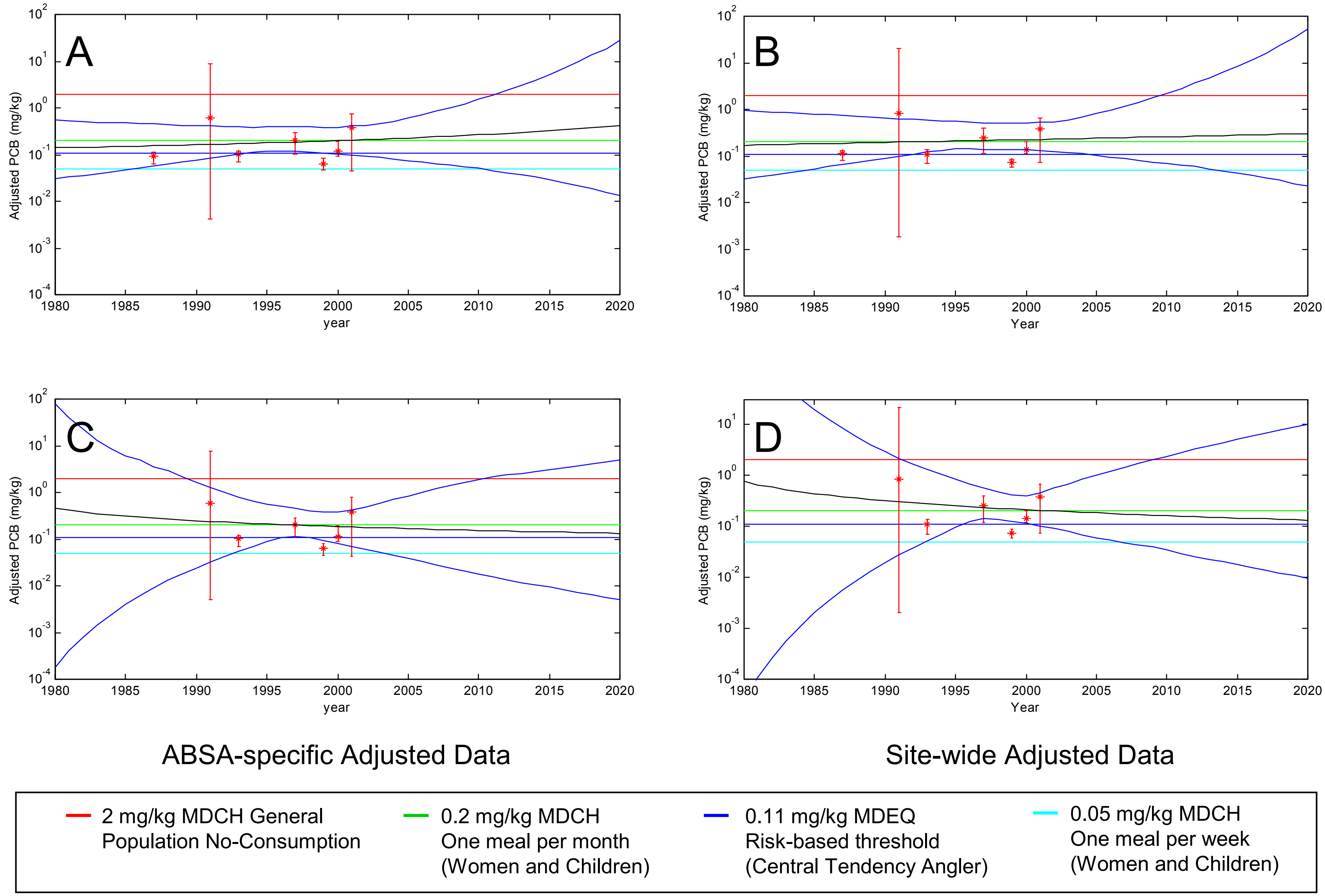
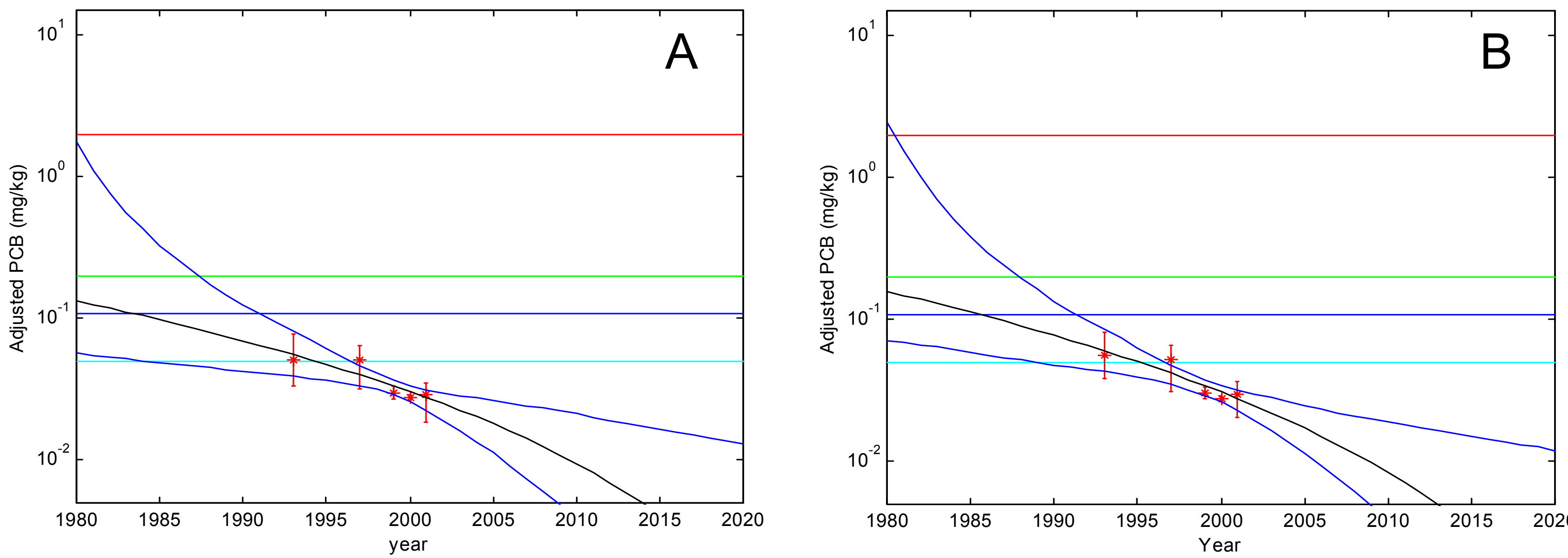


FIGURE 12.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT BATTLE CREEK FOR 1990-2001.



ABSA-specific Adjusted Data

Site-wide Adjusted Data

- 2 mg/kg MDCH General Population No-Consumption
- 0.2 mg/kg MDCH One meal per month (Women and Children)
- 0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)
- 0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 13.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT MORROW POND FOR 1986-2001(PANELS A AND B) AND 1990-2001 (PANELS C AND D).

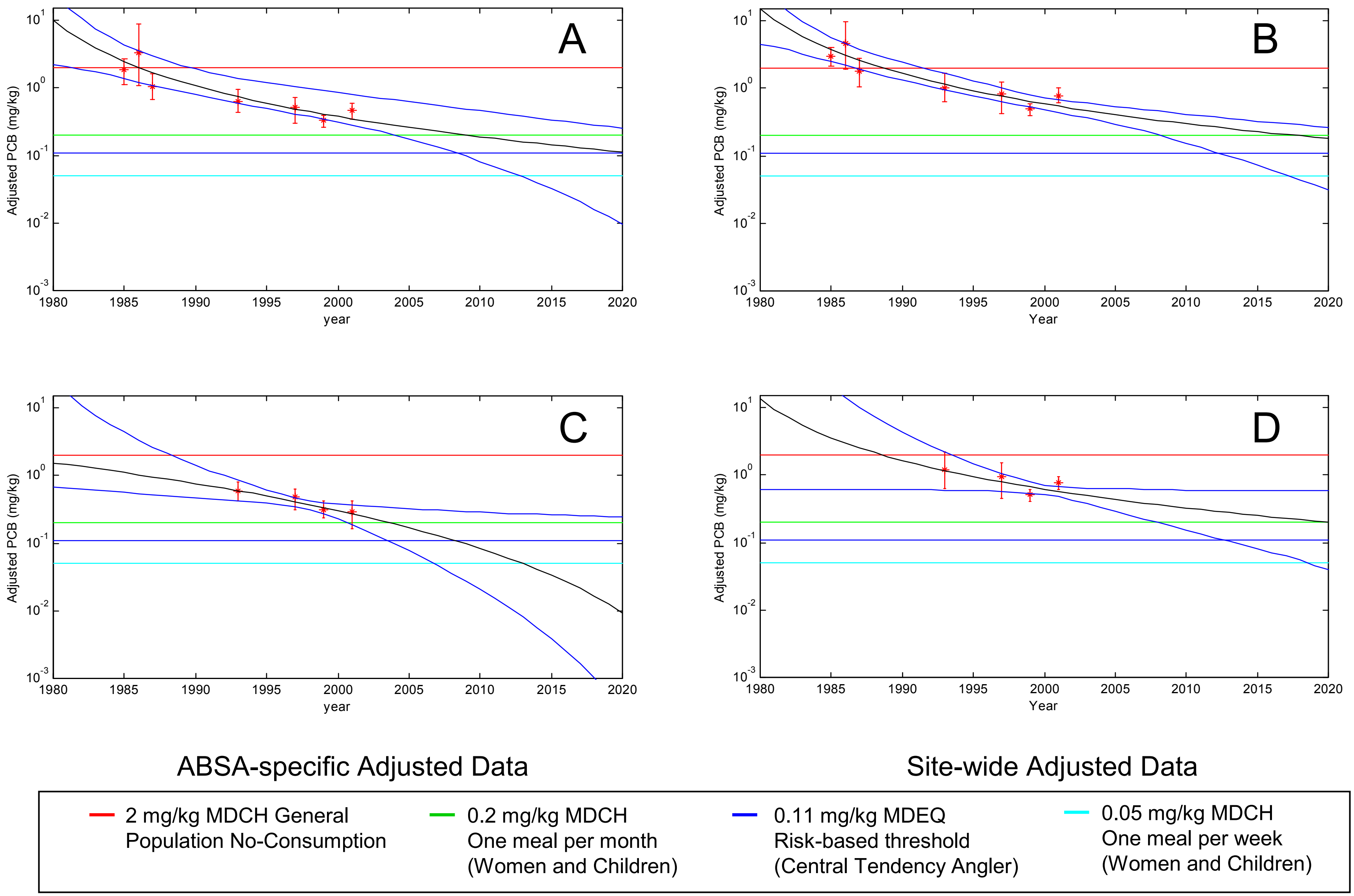
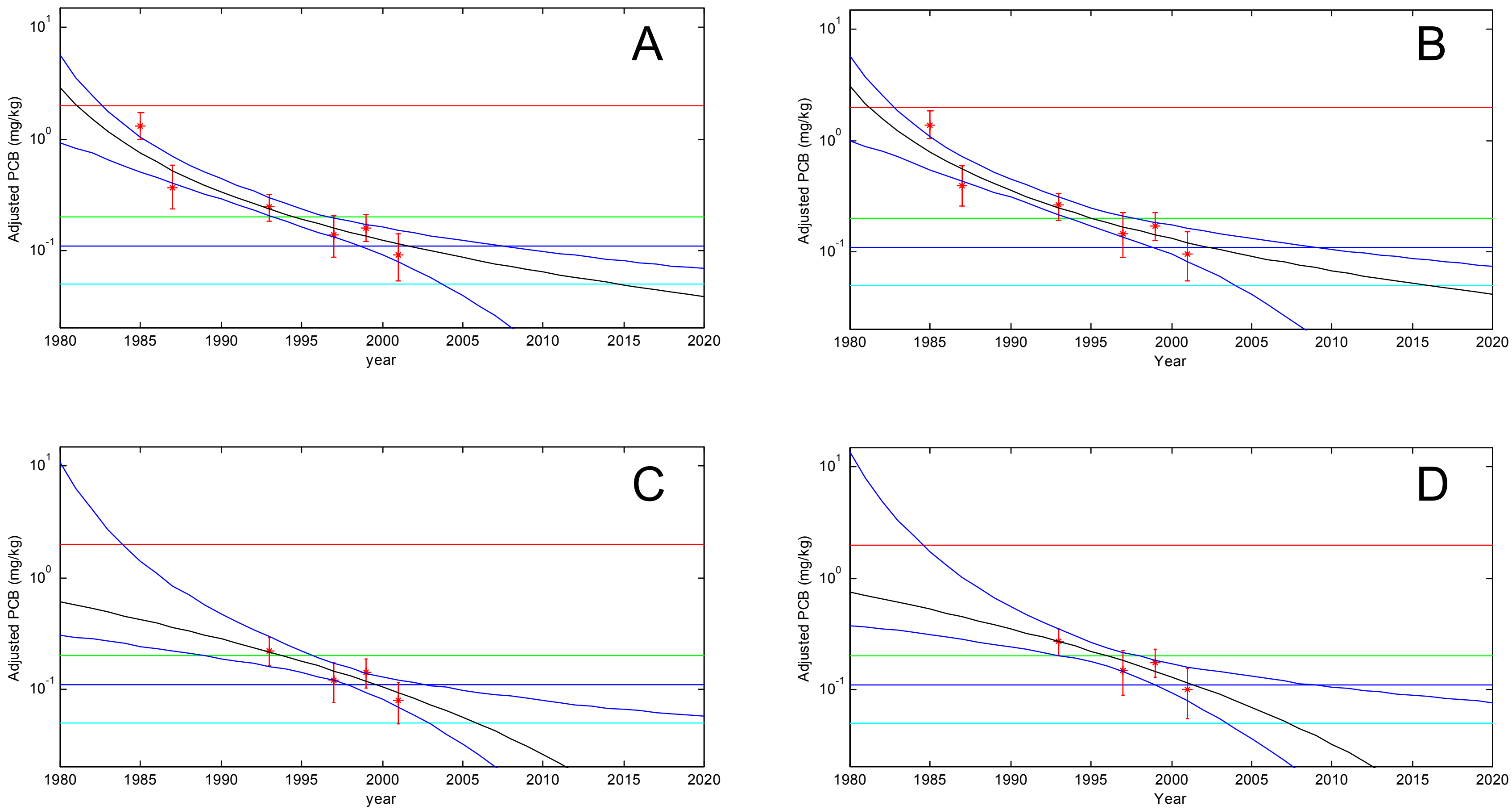


FIGURE 14.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT MORROW POND FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).



ABSA-specific Adjusted Data

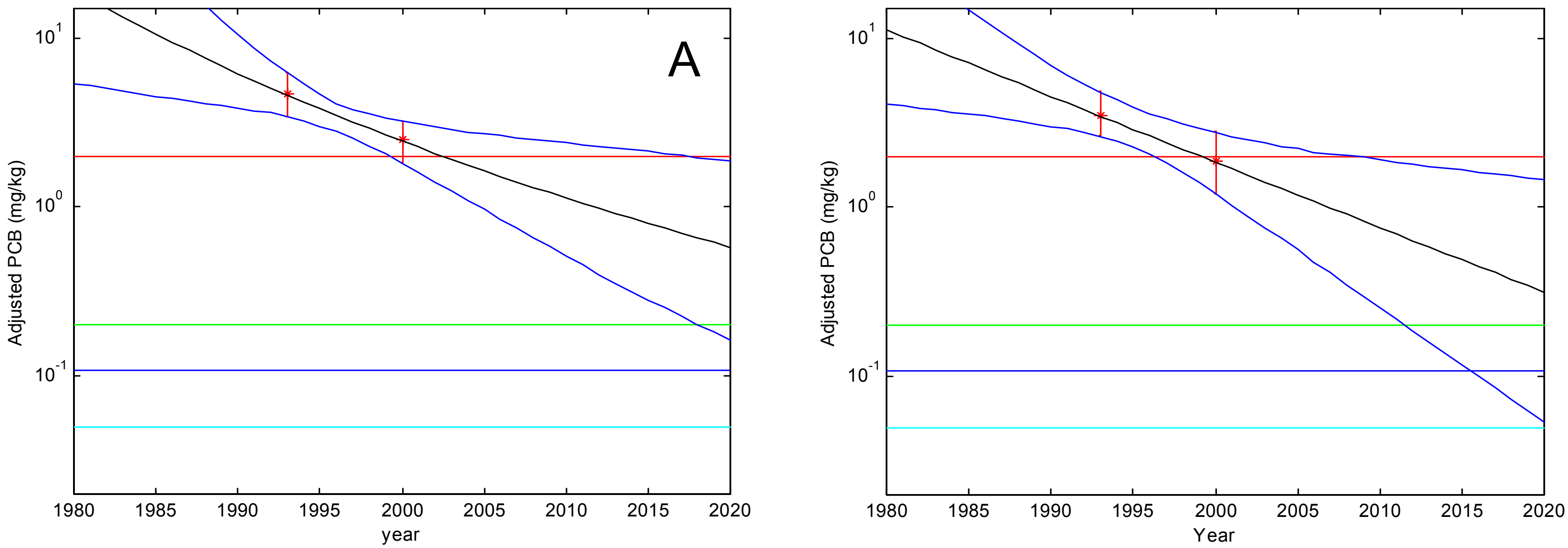
Site-wide Adjusted Data

- 2 mg/kg MDCH General Population No-Consumption
- 0.2 mg/kg MDCH One meal per month (Women and Children)
- 0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)
- 0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 15.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS DOWNSTREAM OF MORROW DAM FOR 1990-2001.



ABSA-specific Adjusted Data

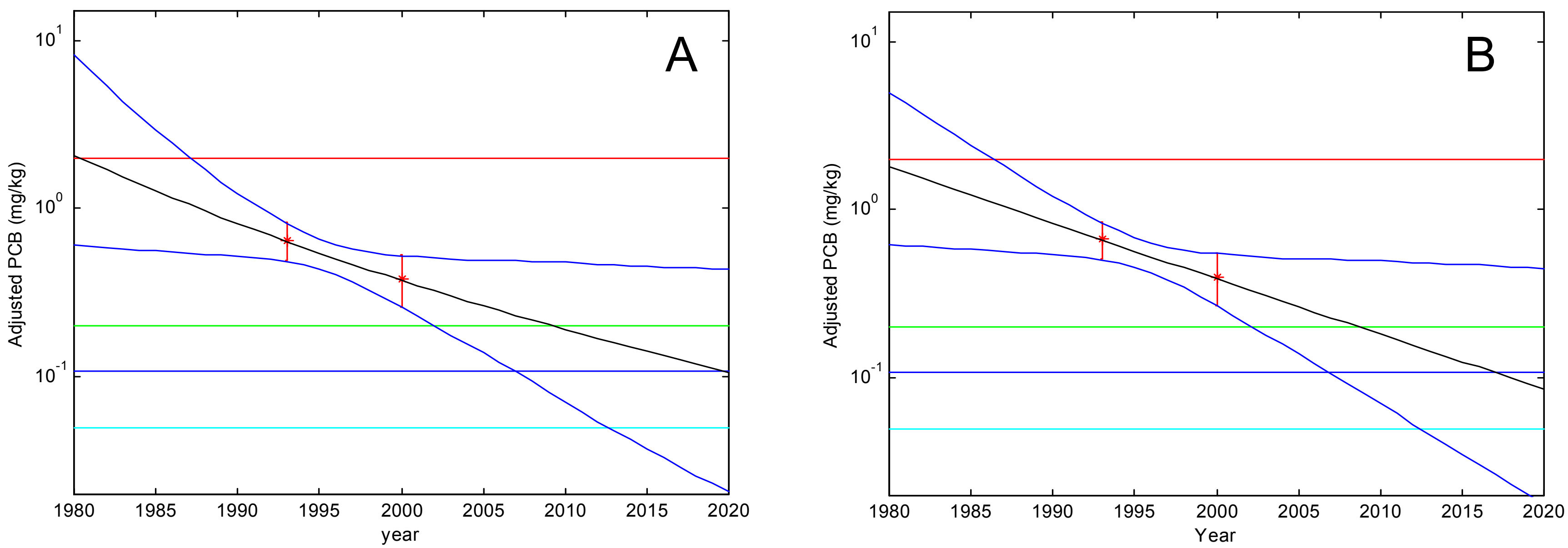
Site-wide Adjusted Data

- 2 mg/kg MDCH General Population No-Consumption
- 0.2 mg/kg MDCH One meal per month (Women and Children)
- 0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)
- 0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 16.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS
DOWNSTREAM OF MORROW DAM FOR 1990-2001.



ABSA-specific Adjusted Data

Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption

0.2 mg/kg MDCH One meal per month (Women and Children)

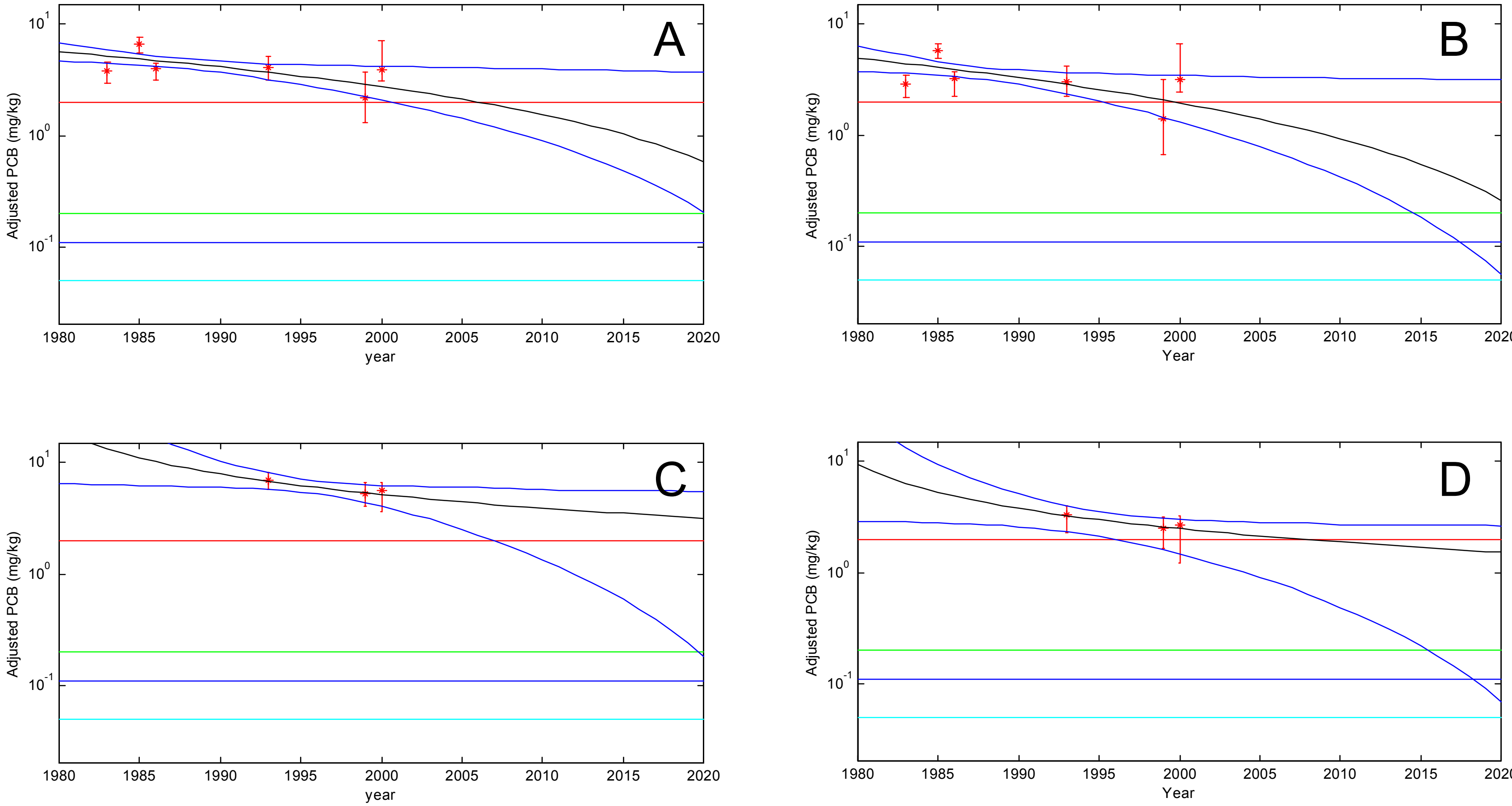
0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)

0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 17.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT MOSEL AVENUE FOR 1983-2001(PANELS A AND B) AND 1990-2001 (PANELS C AND D).



ABSA-specific Adjusted Data

Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption

0.2 mg/kg MDCH One meal per month (Women and Children)

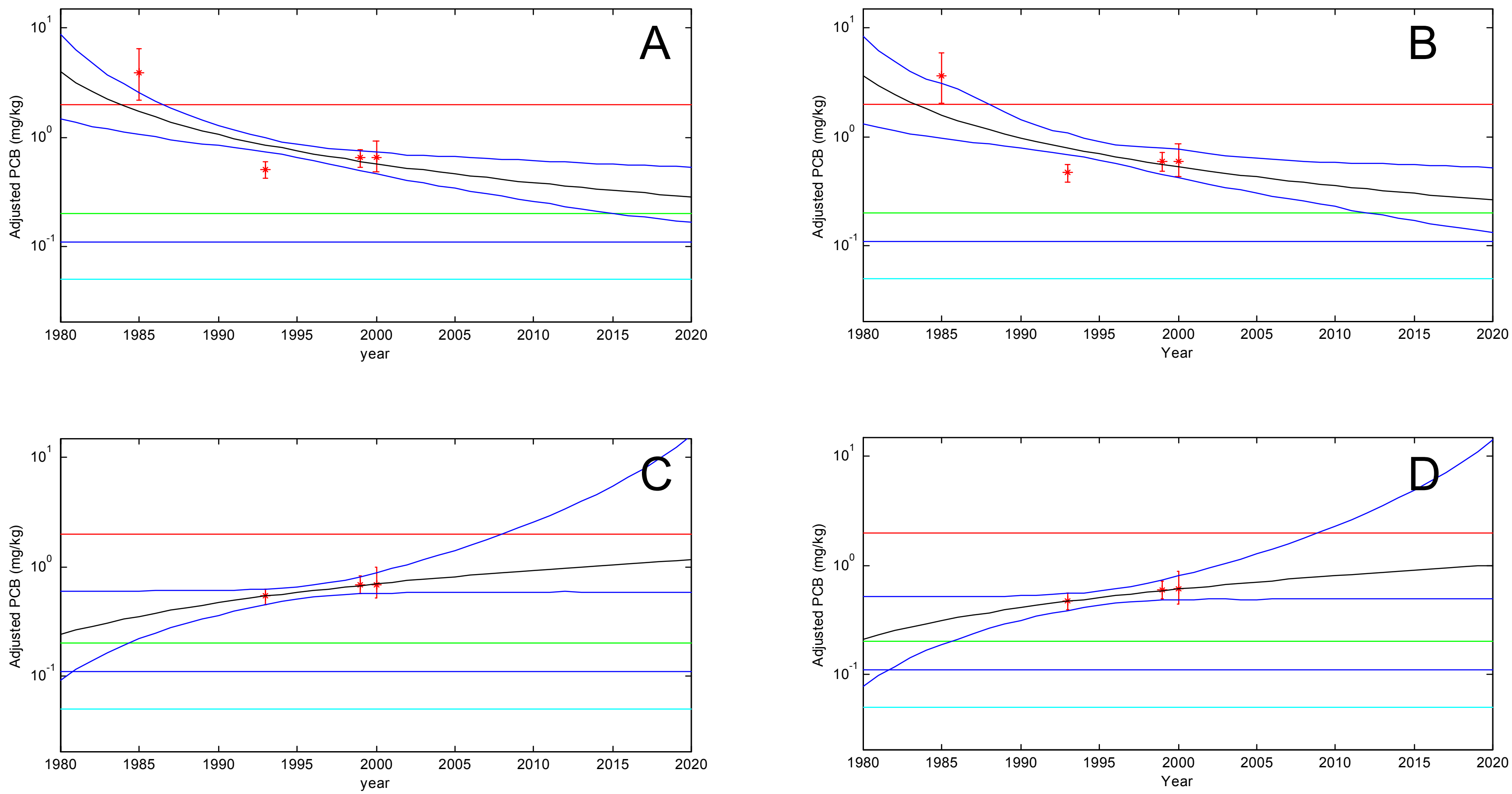
0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)

0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 18.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT MOSEL AVENUE FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).



ABSA-specific Adjusted Data

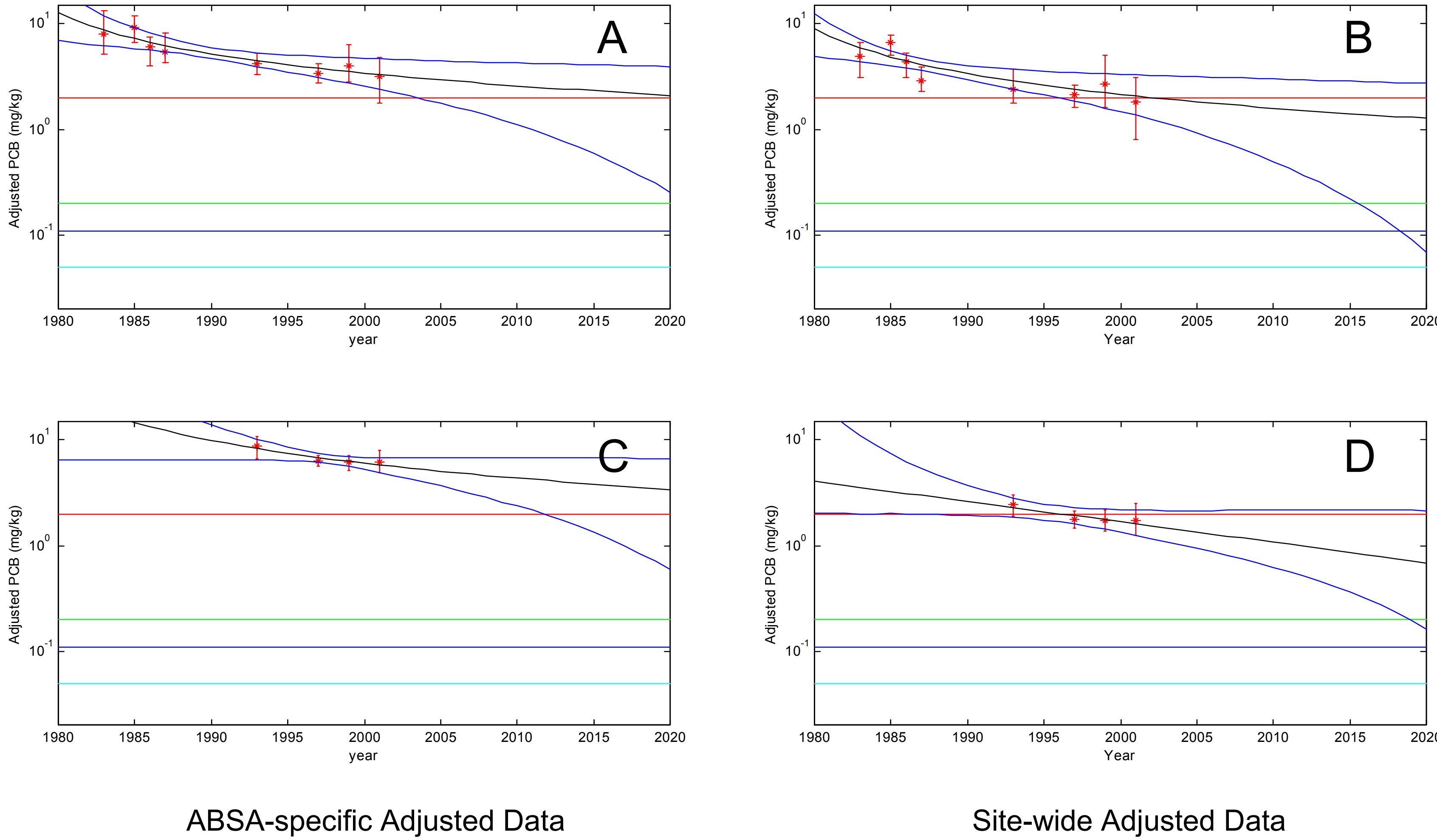
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 19.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT PLAINWELL IMPOUNDMENT FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).



2 mg/kg MDCH General Population No-Consumption

0.2 mg/kg MDCH One meal per month (Women and Children)

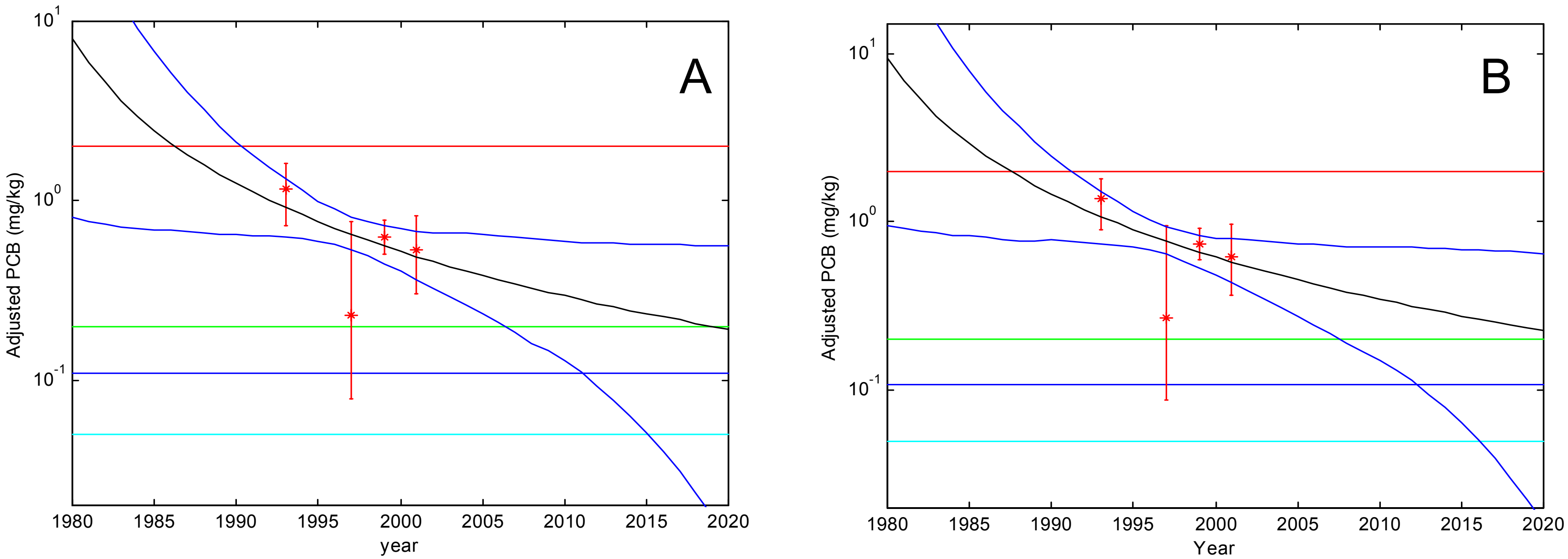
0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)

0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 20.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT PLAINWELL IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

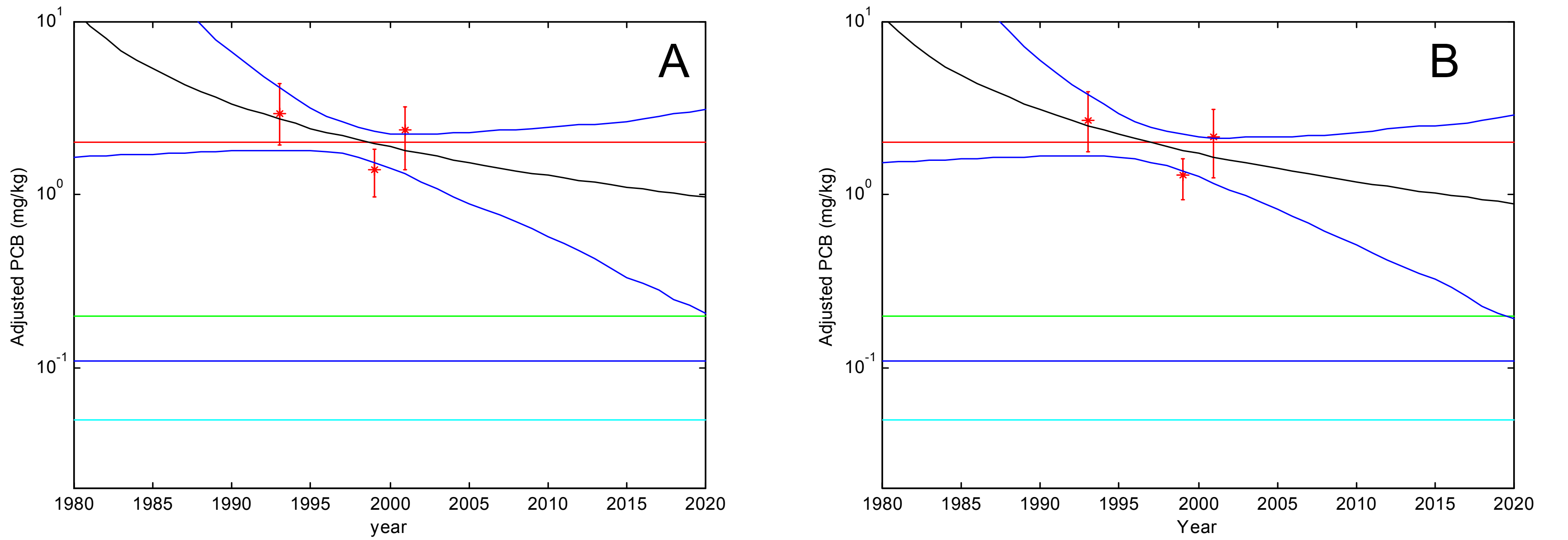
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 21.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT OTSEGO CITY IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

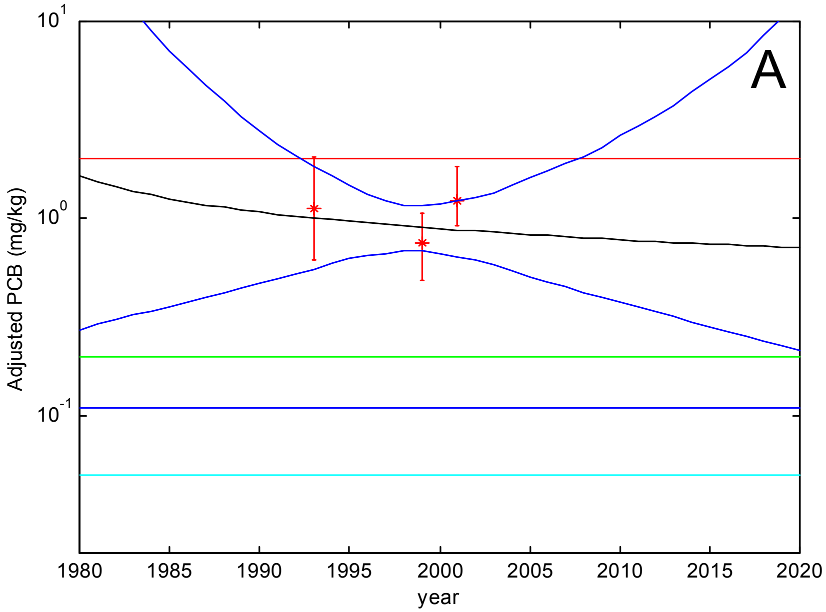
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

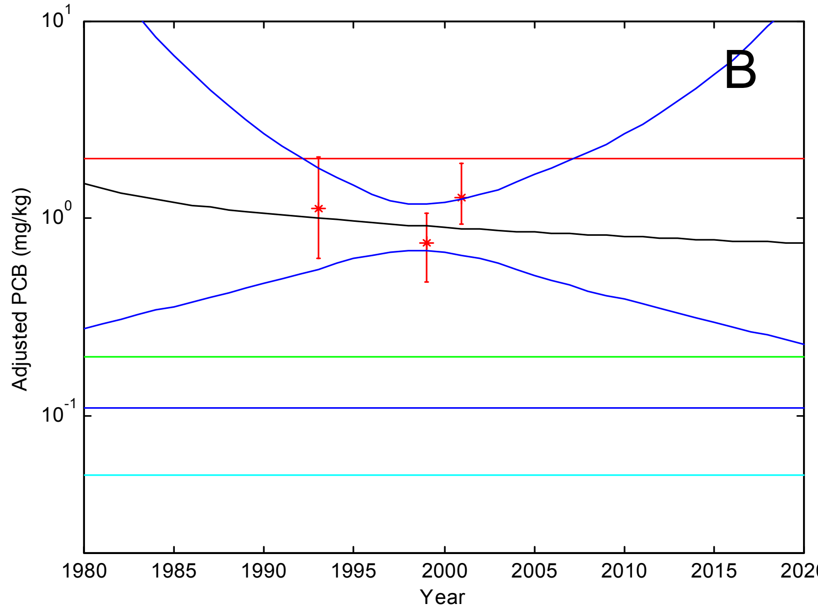
FIGURE 22.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT OTSEGO CITY IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data



Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption

0.2 mg/kg MDCH One meal per month (Women and Children)

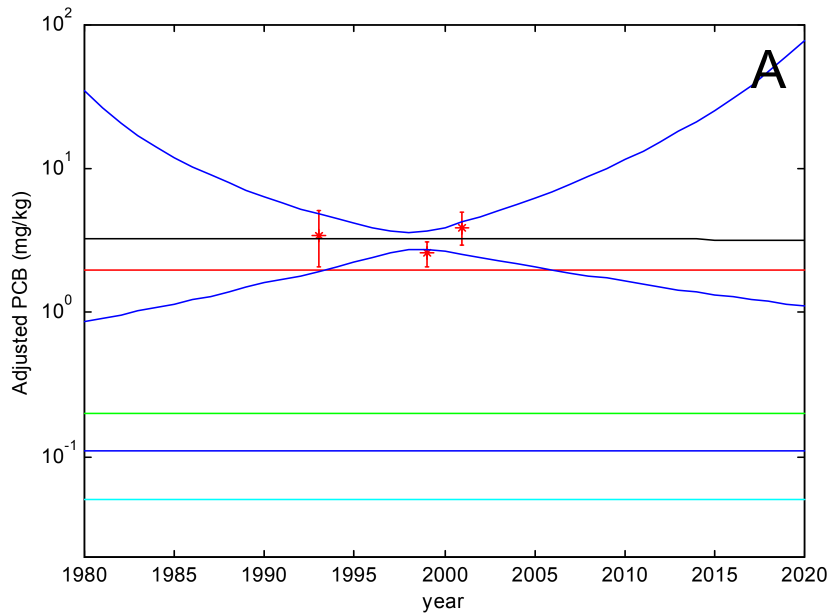
0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)

0.05 mg/kg MDCH One meal per week (Women and Children)

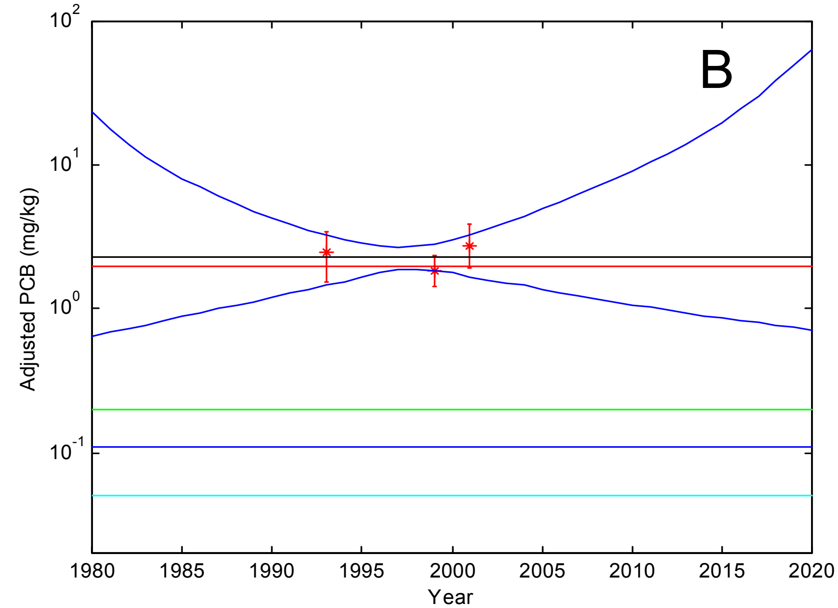
FIGURE 23.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT OTSEGO IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data



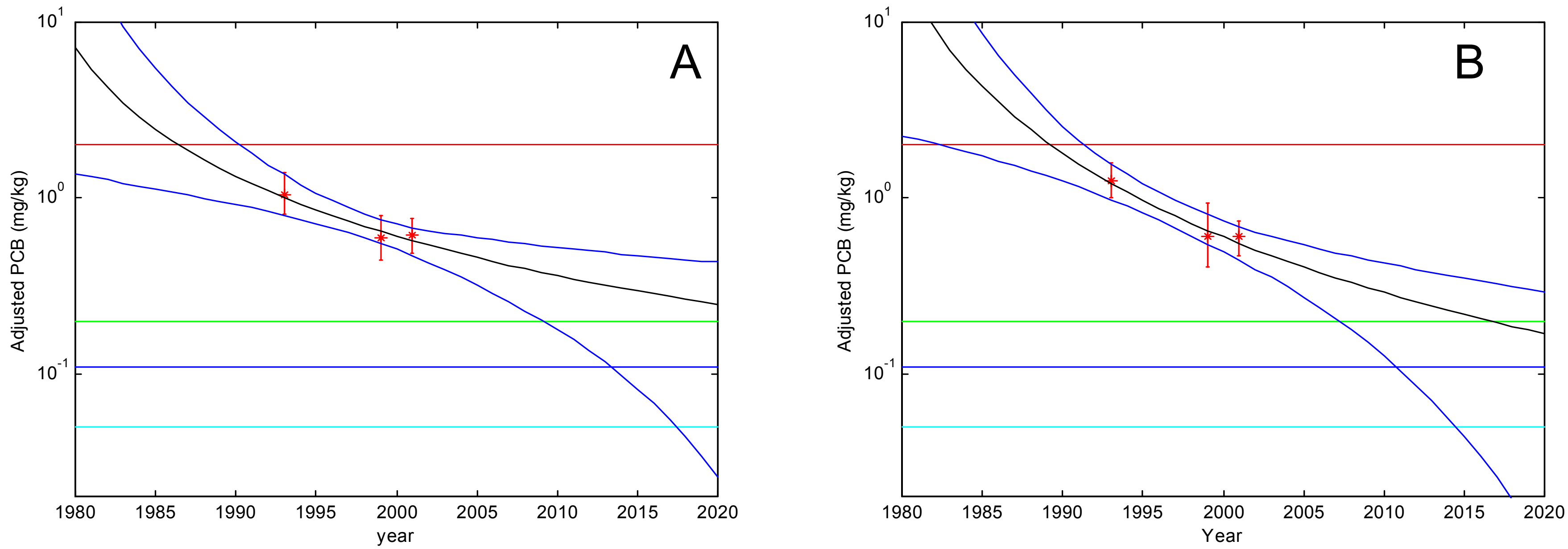
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 24.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT OTSEGO IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

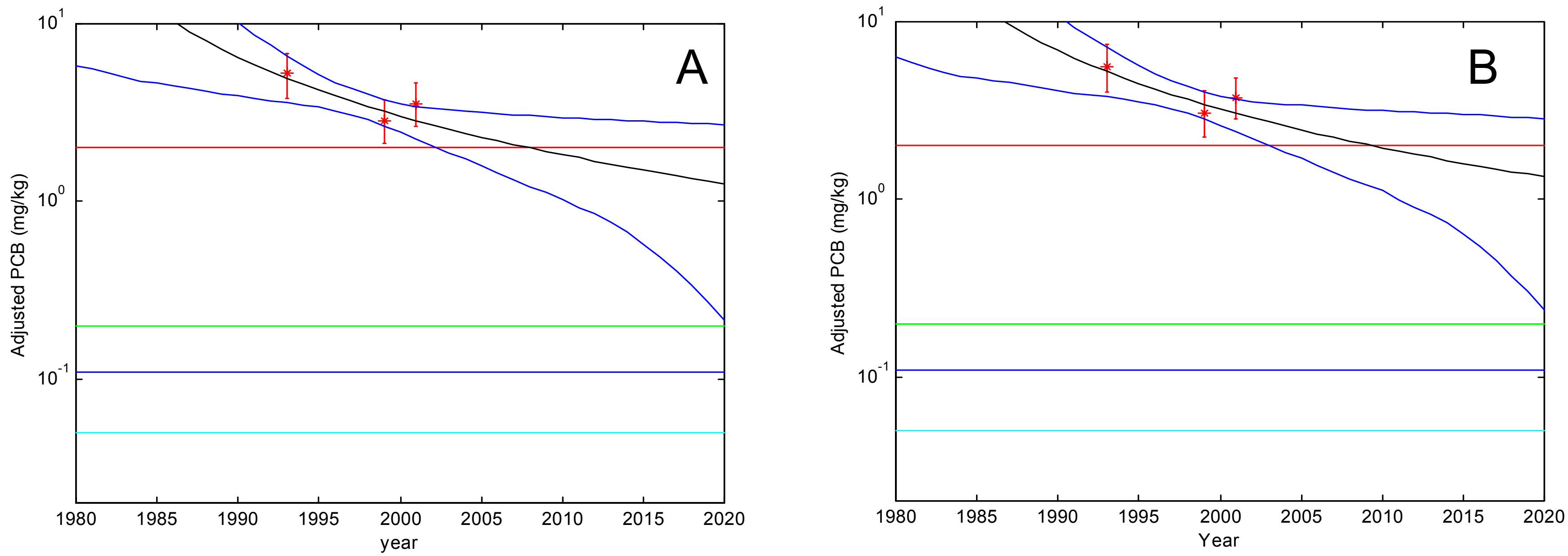
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 25.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT TROWBRIDGE IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

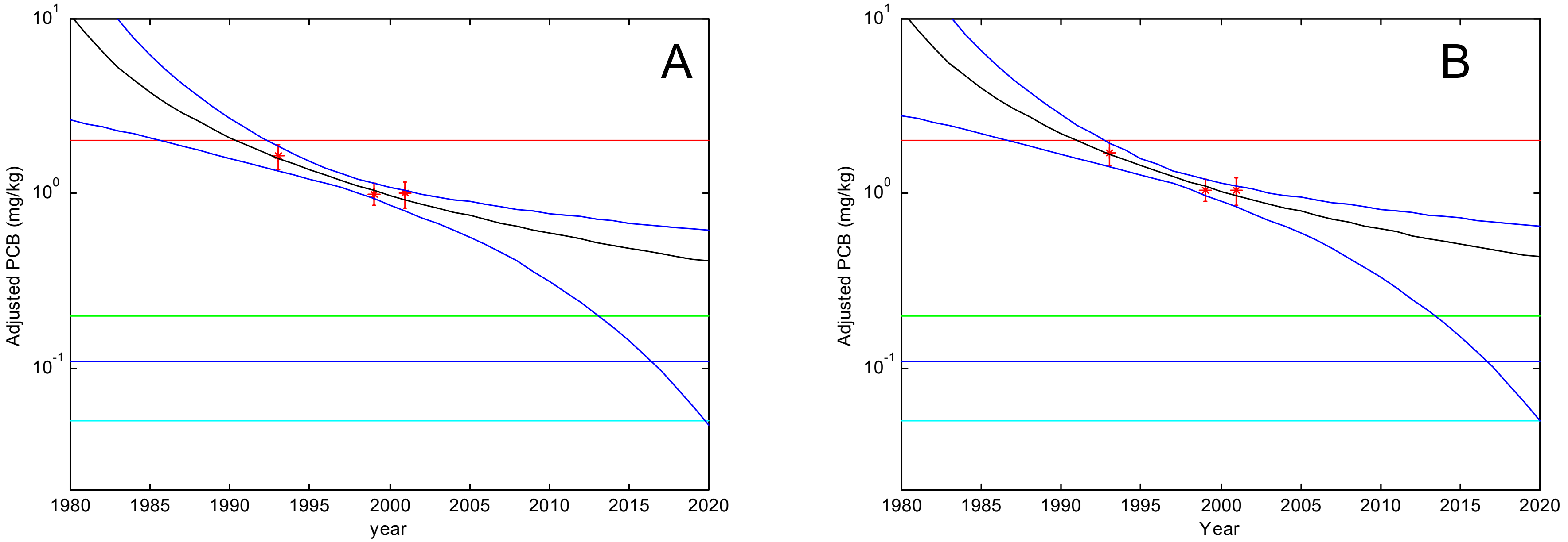
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 26.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT TROWBRIDGE IMPOUNDMENT FOR 1990-2001.



ABSA-specific Adjusted Data

Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption

0.2 mg/kg MDCH One meal per month (Women and Children)

0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)

0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 27.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT LAKE ALLEGAN FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).

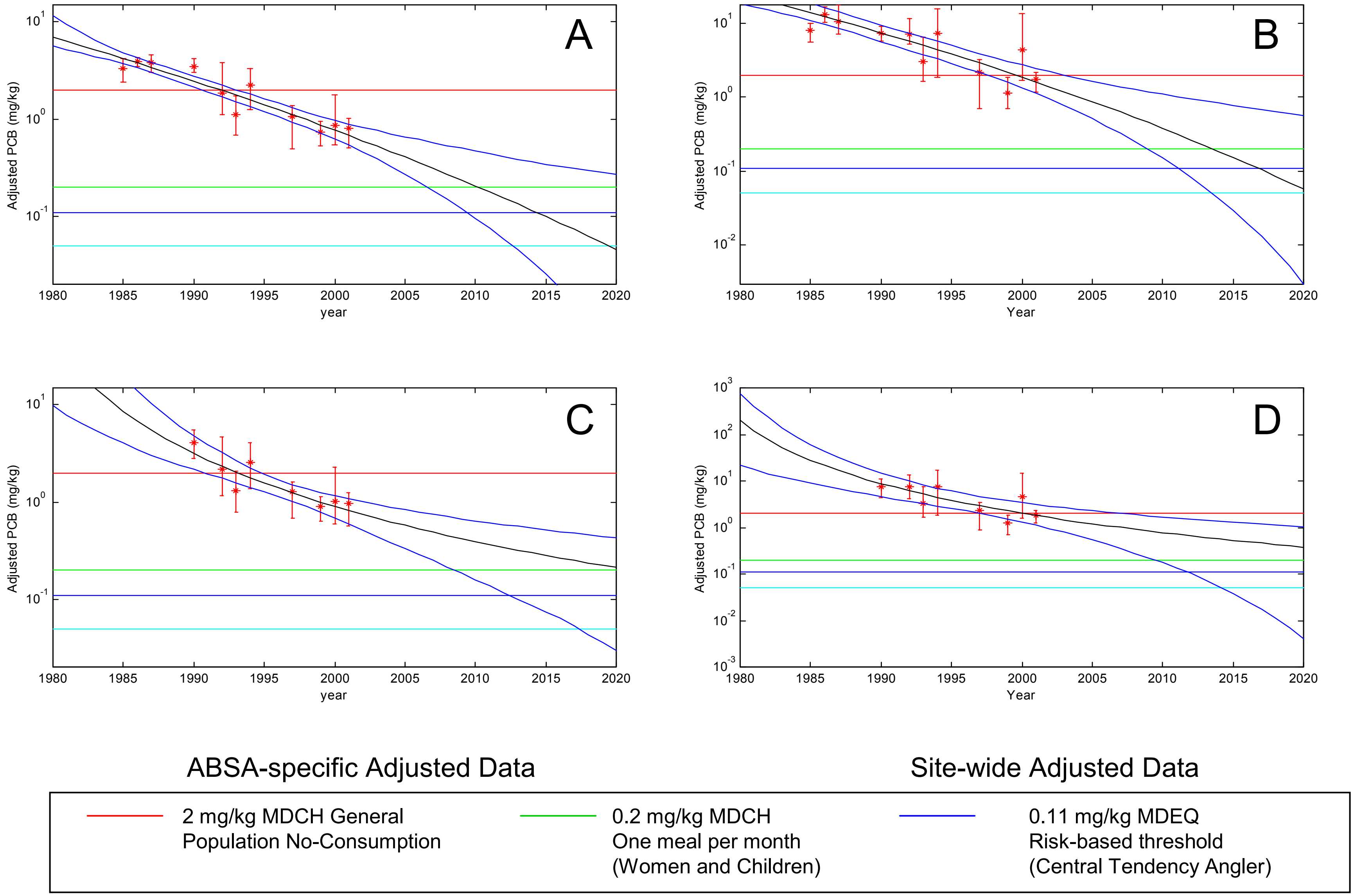


FIGURE 28.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT LAKE ALLEGAN FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).

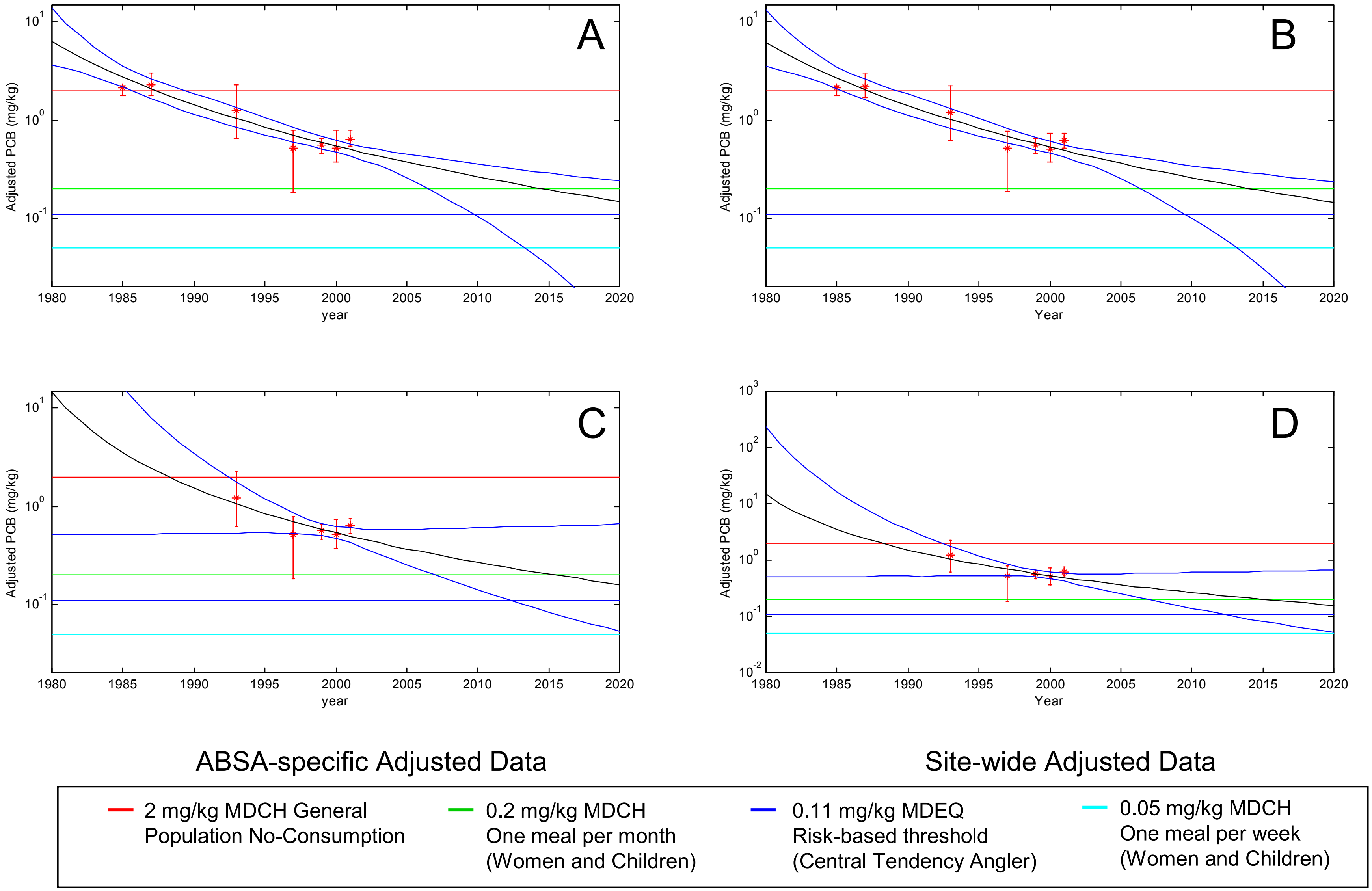


FIGURE 29.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT NEW RICHMOND FOR 1990-2001.

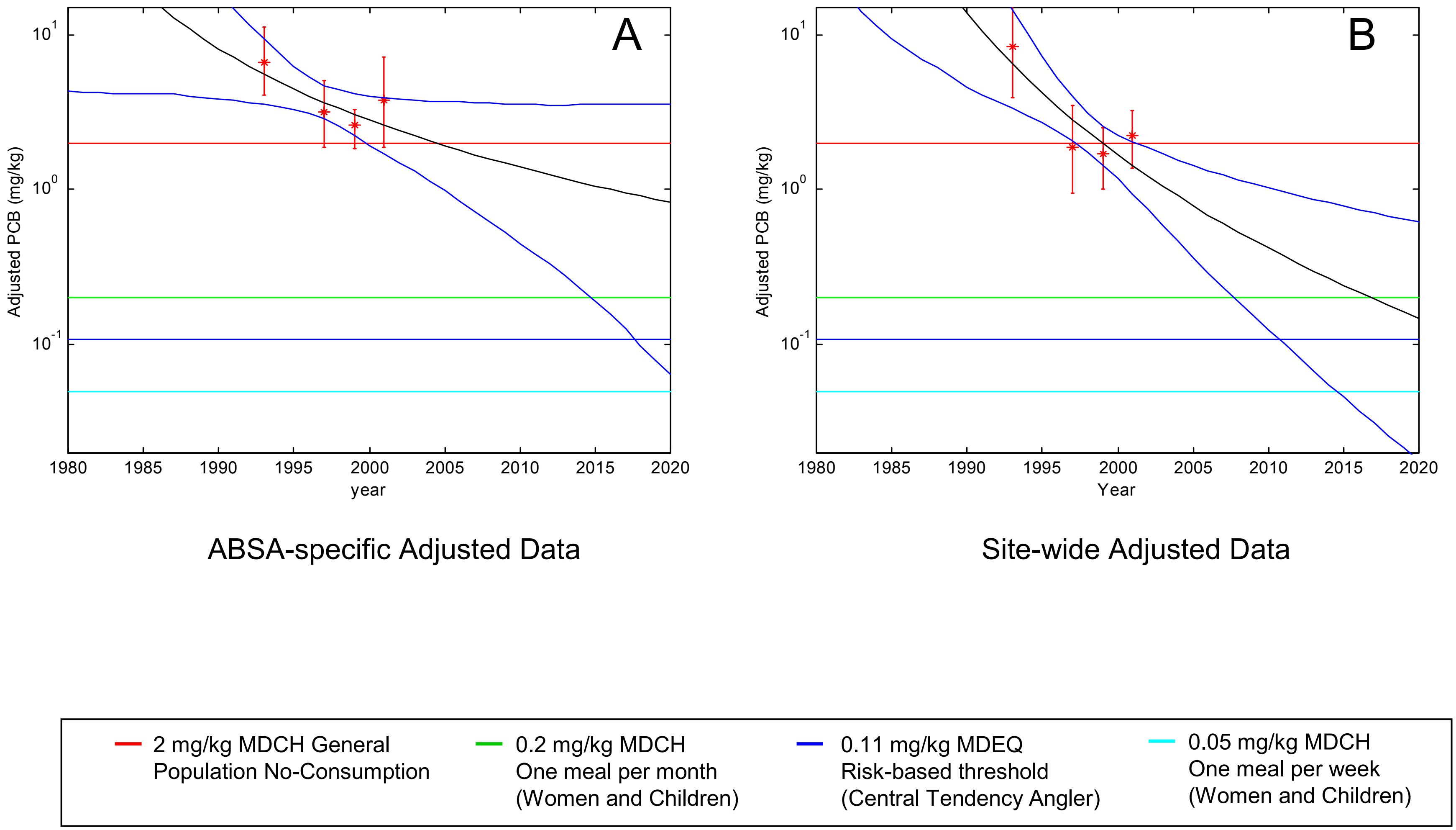
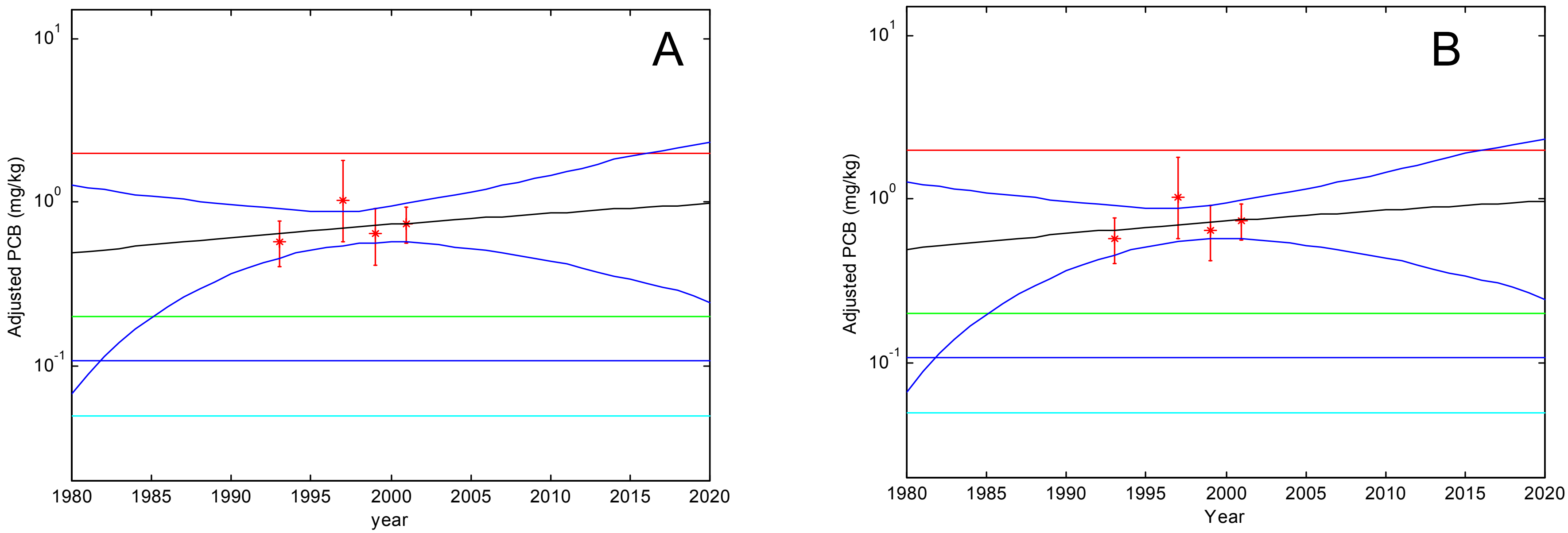


FIGURE 30.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT NEW RICHMOND FOR 1990-2001.



ABSA-specific Adjusted Data

Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption

0.2 mg/kg MDCH One meal per month (Women and Children)

0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)

0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 31.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN COMMON CARP FILLETS AT SAUGATUCK FOR 1983-2001 (PANELS A AND B) AND 1990-2001 (PANELS C AND D).

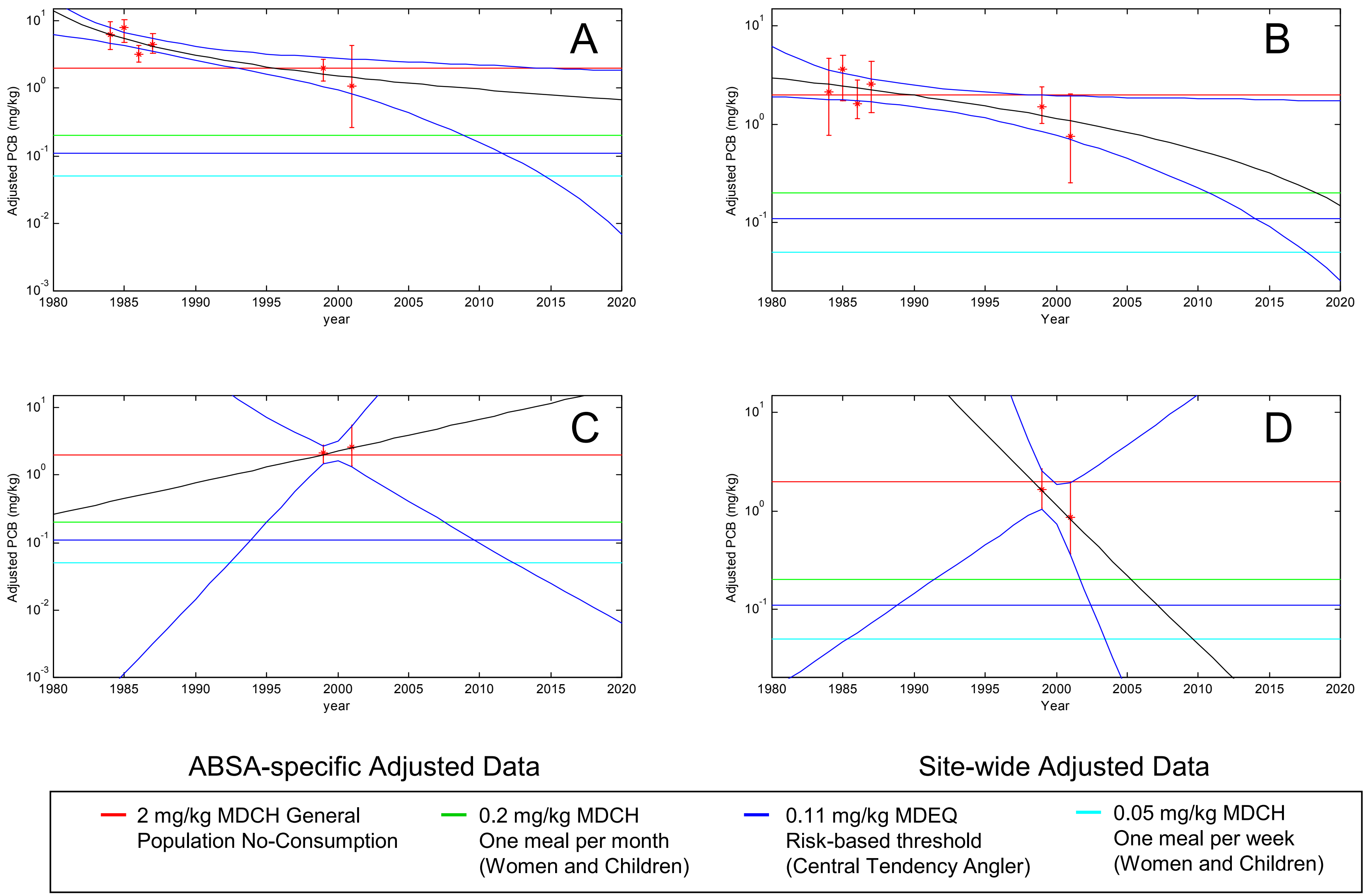
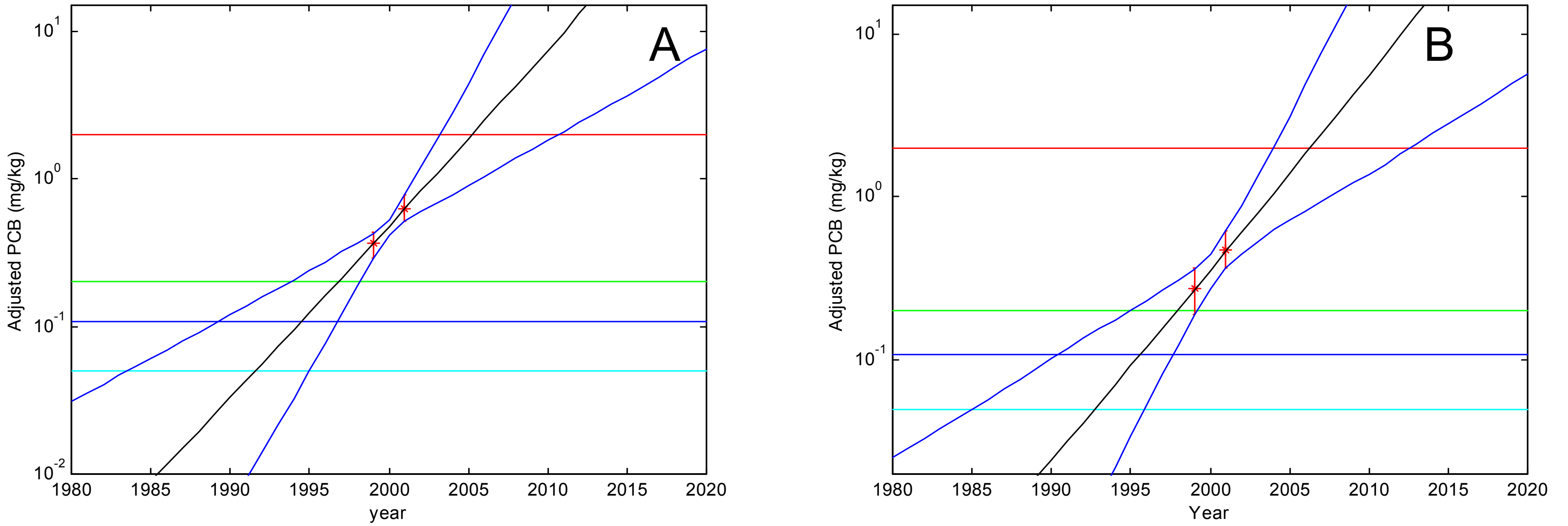


FIGURE 32.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

TEMPORAL TRENDS IN LIPID AND LENGTH ADJUSTED PCB CONCENTRATION IN SMALLMOUTH BASS FILLETS AT SAUGATUCK FOR 1990-2001.



ABSA-specific Adjusted Data

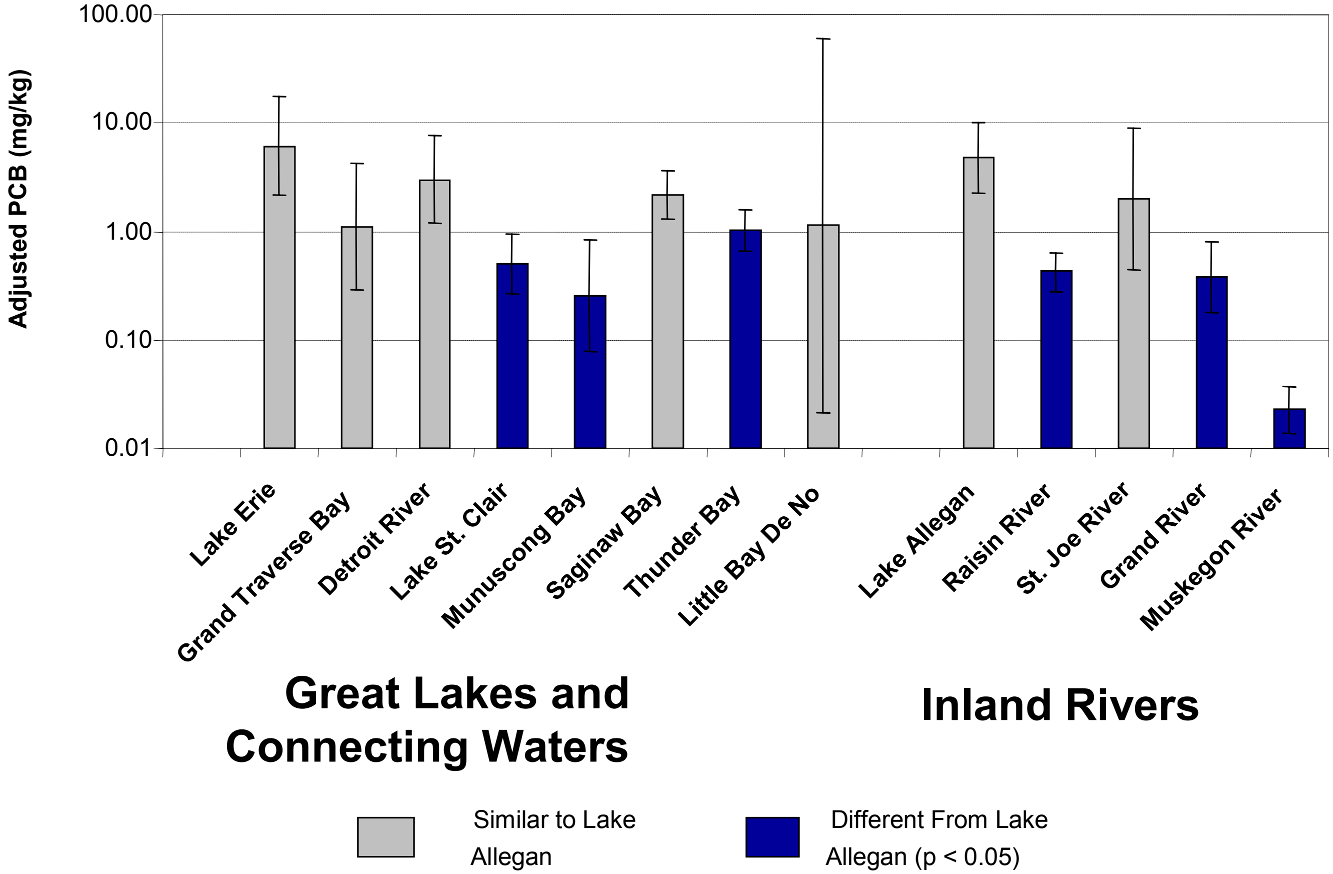
Site-wide Adjusted Data

2 mg/kg MDCH General Population No-Consumption	0.2 mg/kg MDCH One meal per month (Women and Children)	0.11 mg/kg MDEQ Risk-based threshold (Central Tendency Angler)	0.05 mg/kg MDCH One meal per week (Women and Children)

FIGURE 33.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

LENGTH AND LIPID ADJUSTED PCB CONCENTRATION IN WHOLE BODY CARP
AT TREND MONITORING STATIONS WITHIN THE STATE OF MICHIGAN

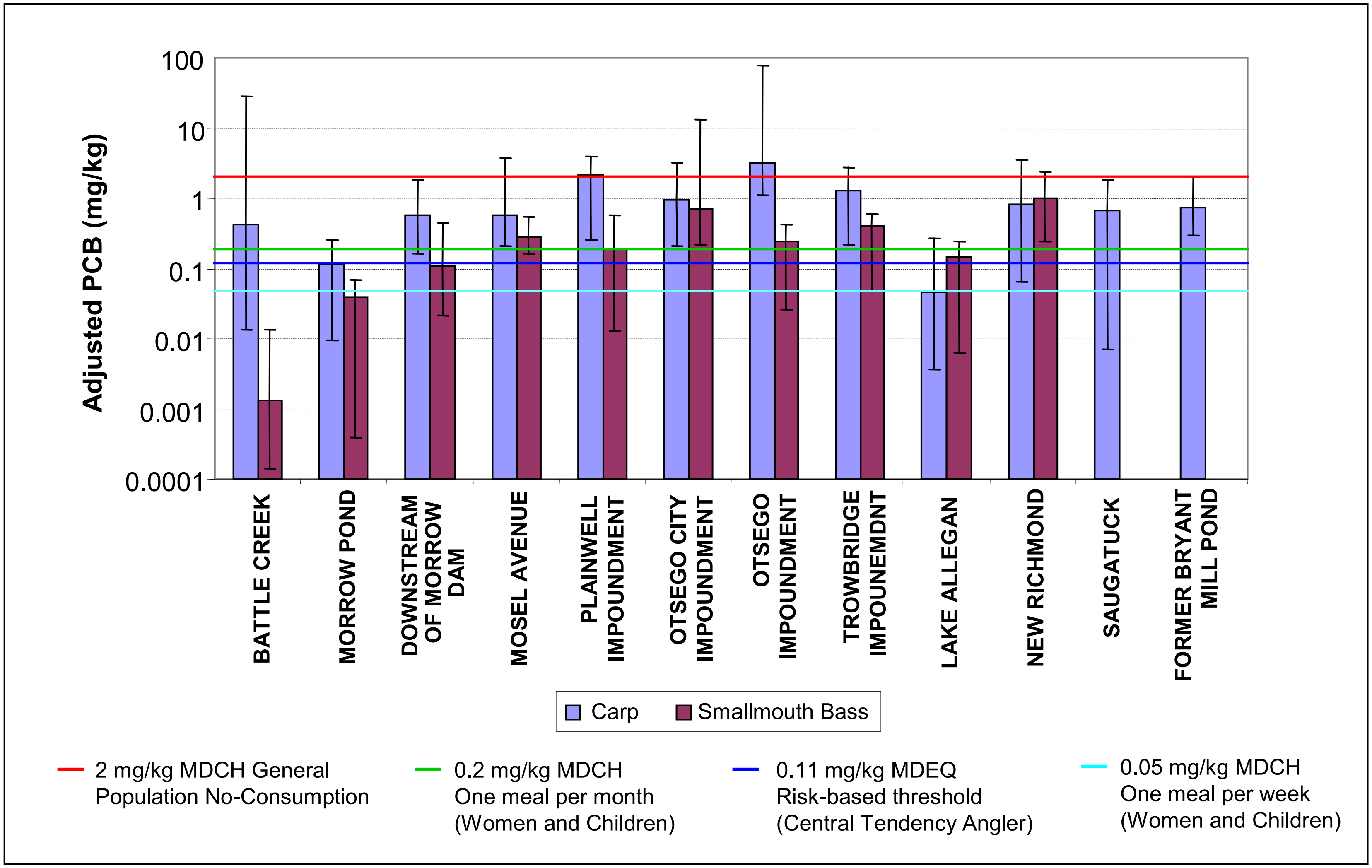


Notes:
1. Bars represent mean length- and lipid-adjusted PCB concentration in whole body carp.
2. Error bars represent 95% confidence limits.
3. White bars represent mean adjusted PCB concentrations that are significantly less than the mean concentration at Lake Allegan at the 5% significance level using Duncan's multiple comparison procedure.

FIGURE 34.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PROJECTED PCB CONCENTRATION IN CARP AND SMALLMOUTH BASS FILLETS IN 2020



Notes:

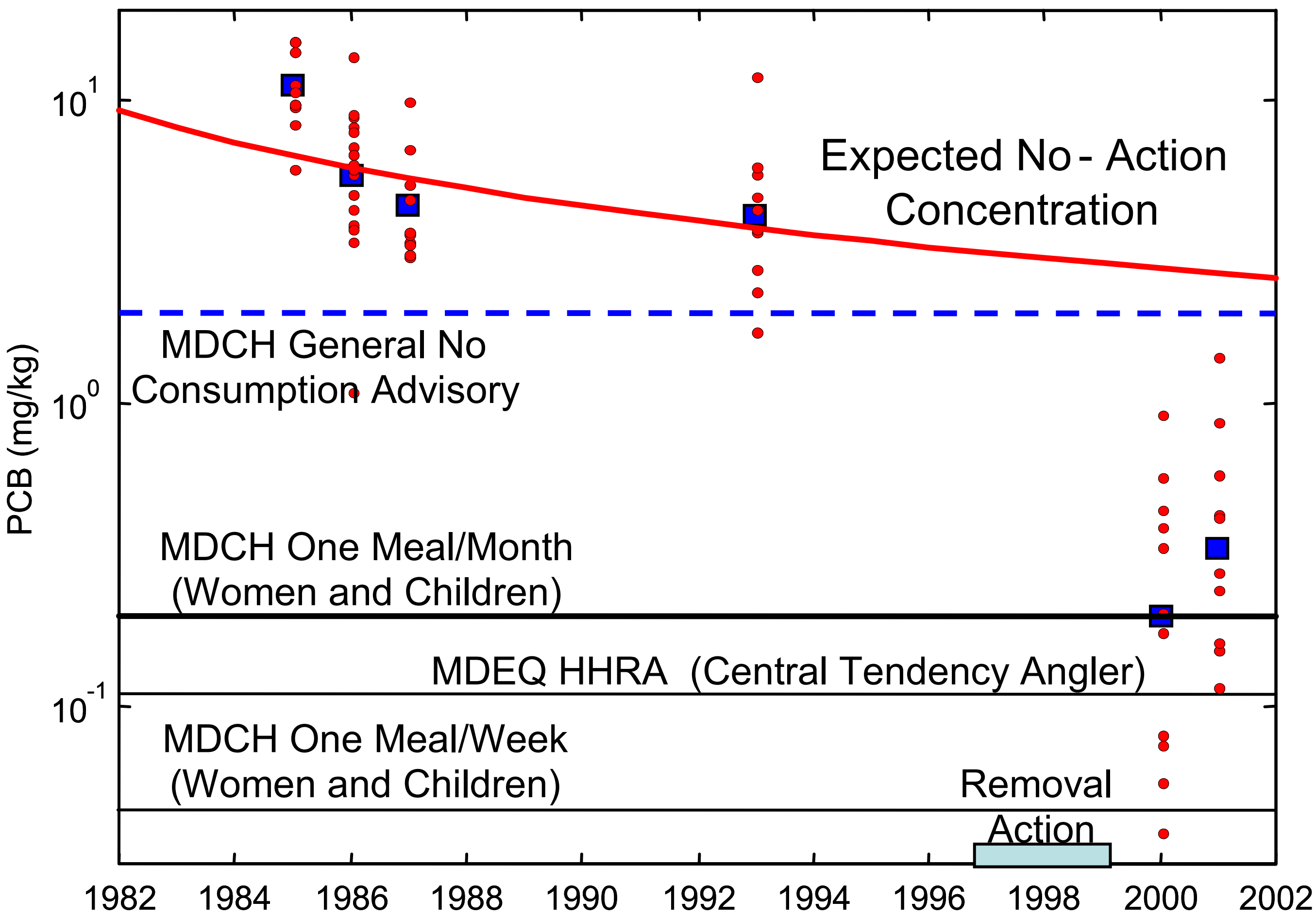
1) Projectied concentrations for Bryant Mill Pond are based on data collected prior to the removal action in 1999 and reflect what would have been expected had the removal not been conducted.

2) Bars represent the best fit MO temporal trend model for the mean, and error bars represent 95% bootstrap confidence intervals..

FIGURE 35.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PERFORMANCE OF INTERIM REMOVAL ACTION AT FORMER BRYANT MILL POND

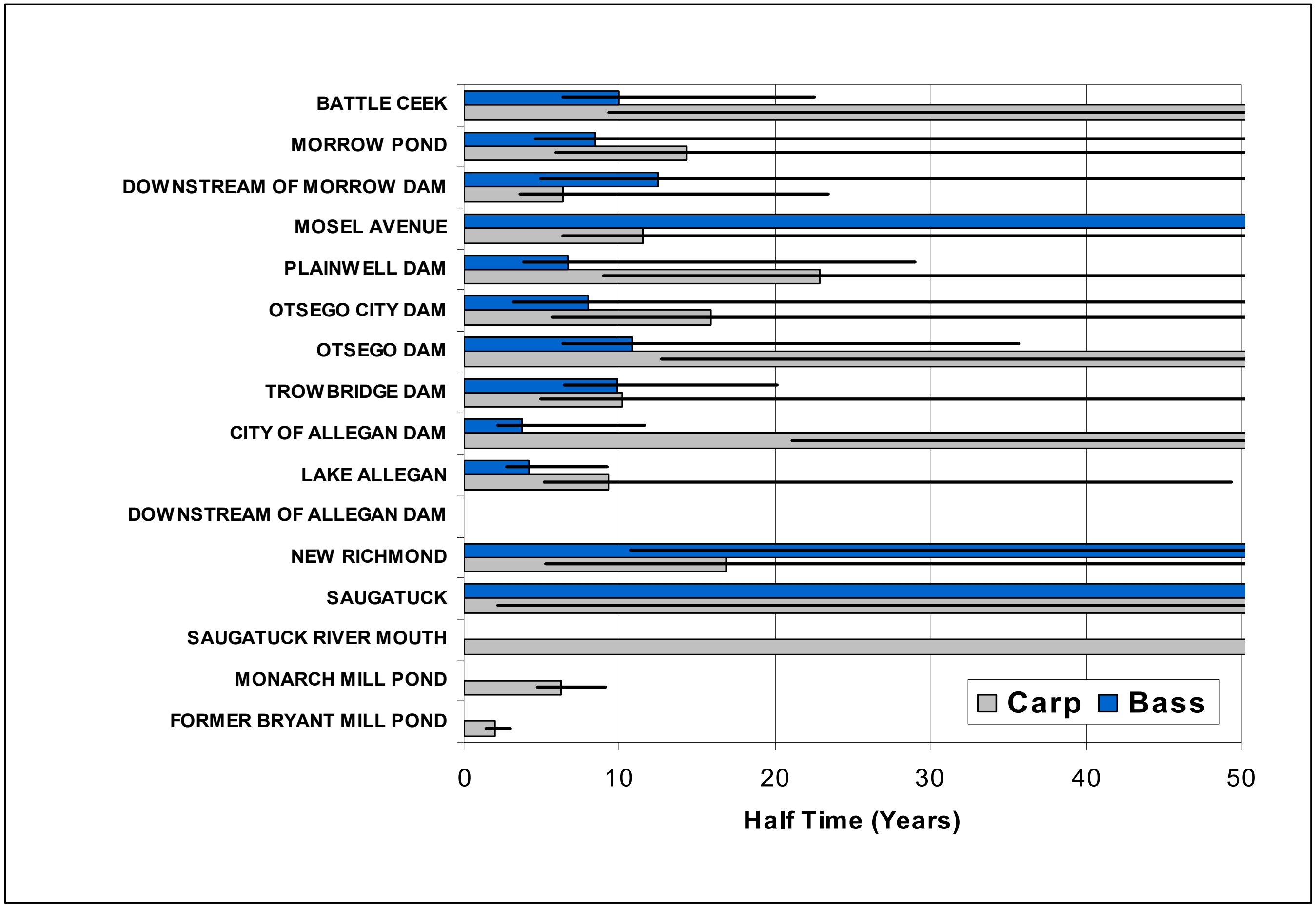


Notes:
1. Red line represents forecasted no-action alternative.

FIGURE 36.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FISH TREND ANALYSIS

PCB HALF-TIME IN KALAMAZOO RIVER FILLETS (1990-2001)



Notes:

1. Bars represent estimated half-time and solid lines represent 95% confidence intervals.
2. Bars extending to 50 years indicate that concentrations are not decreasing and therefore there is no half time.
3. Solid lines extending to 50 years indicate that decreasing trends are not significant and therefore upper confidence limits are greater than 50 years.
4. Half-times are adjusted for covariation between PCB concentration, lipid content in samples and fish-length.
5. Monarch Mill and Former Bryant Mill Ponds are listed last because they are on Portage Creek, rather than the Kalamazoo River

Appendix A.

Example Calculations for Lipid- and Length-Adjusted PCB Concentration

PCB concentration was correlated with lipid-fraction ($p < 0.05$) in both Carp and Smallmouth Bass fillets at all sites where trends were estimated (Table 2). Additionally, after adjusting for covariation with lipid-fraction, PCB concentration in carp fillets was correlated with fish-length ($p<0.05$) at Morrow Pond, Plainwell Impoundment, Otsego City Impoundment and Saugatuck. After Adjusting for covariation with lipid-fraction, PCB concentration in smallmouth bass fillets was correlated with fish-length ($p<0.05$) at Battle Creek, Plainwell Impoundment and Saugatuck.

A summary of estimated regression coefficients can be found in Table (3). The reported significance levels are based on the conditional test procedure described by Neter et al (1996). When year-by-lipid or year-by-length interactions were statistically significant, the corresponding main effects were retained in the model, so the statistical significance of those effects is not reported.

These regression coefficients were used to adjust wet-weight PCB data.
Adjusted PCB concentrations are calculated in four steps:

1) Calculate the regression function (predicted concentration) at the observed lipid and length values.

2) Calculate the regression residual by subtracting the predicted concentration from the log of the wet-weight PCB concentration.

3) Calculate the expected concentration for a representative fish by using the regression equation with the site-wide average length and lipid-fraction.

4) Add the residual calculated in (2) to the expected concentration from (3) and finally exponentiate the result to obtain adjusted PCB concentration.

Example 1: Consider a hypothetical smallmouth bass captured at Morrow Pond in 1997 with 0.8 mg/kg wet-weight PCB, 0.4% lipid fraction and 32 cm in length. The model for smallmouth bass at Morrow Pond is

1) Calculate the predicted value

$$Predicted = \beta_0 - \beta_{year} + \beta_{lipid} \times \log(lipid).$$
$$Predicted = 0.43 - 2.26 + 0.71 \times \log(0.4) = -2.4806$$

2) Calculate the residual. The predicted value was already in log-scale, but the actual value was not.

$$Residual = \log(0.8) - (-2.4806) = 2.2575$$

3) Calculate adjustment term based upon site-wide representative smallmouth bass that is 33 cm long and has .696% lipid fraction.

$$Expected_{Site-wide} = 0.43 - 2.26 \times (1) + 0.71 \times \log(0.696) = -2.0856$$

4) Calculate final adjusted value.

$$PCB_{Adjusted} = \exp(-2.0856 + 2.2575) = 1.19$$

Example 2: Consider two hypothetical carp from Saugatuck, each with 2.5 mg/kg wet-weight PCB, 7% lipid fraction and 59 cm in length, but one captured in 1999 and the other captured in 2001. The model for Saugatuck carp is

$$\begin{aligned} Pred_{year} &= \beta_0 + \beta_{year} + \beta_{lipid} \times \log(lipid) + \beta_{length} \times \log(length) \\ &+ \beta_{lipid \times year} \times \log(lipid) + \beta_{length \times year} \times \log(length). \end{aligned}$$

Note that the terms that involve year are different for each year (see Table 3). Following the adjustment procedure and using the values from Table 3, we have:

1) Calculate the regression function (predicted concentration) at the observed lipid and length values for each fish:

$$\begin{aligned} Pred_{1999} &= -.68 - 0.08 + 1.31 \times \log(7) + 0.09 \times \log(59) \\ &- 1.00 \times \log(7) + 0.10 \times \log(59) = .618 \end{aligned}$$

$$\begin{aligned} Pred_{2001} &= -.68 - 35.63 + 1.31 \times \log(7) + 0.09 \times \log(59) \\ &- 1.15 \times \log(7) + 9.0 \times \log(59) = 1.066 \end{aligned}$$

2) Calculate the regression residual:

$$Residual_{1999} = \log(2.5) - .618 = 0.298$$

$$Residual_{2001} = \log(2.5) - 1.066 = -.150$$

3) Calculate the expected concentration for a fish that is representative of the site. Site-wide, the representative carp is 50.876 cm in length and 1.967% lipid fraction.

$$Expected_{1999} = -.68 - 0.08 + 1.31 \times 0.67 + 0.09 \times 3.93$$
$$- 1.00 \times 0.67 + 0.10 \times 3.93 = .194$$

$$Expected_{2001} = -.68 - 35.63 + 1.31 \times \log(1.967) + 0.09 \times \log(50.876)$$
$$- 1.15 \times \log(1.967) + 9.0 \times \log(50.876) = -.484$$

4) Calculate the adjusted values. Note that even though the fish were identical except for capture year, their adjusted values are different. This is because effect of lipid and length on PCB concentration varies from year to year

$$ADJPCB_{1999} = \exp(.298 + .194) = 1.64$$

$$ADJPCB_{2001} = \exp(-.150 - .484) = .530$$